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Waste Minimization Audit Report: Case Studies of Corrosive and Heavy Metal Waste Minimization at a Specialty Steel Manufacturing Complex

Versar, Inc., Springfield, VA

Prepared for

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WASTE MINIMIZATION AUDIT REPORT

Case Studies of Corrosive and Heavy Metal Waste Minimization at a Specialty Steel Manufacturing Complex

Submitted by:

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Springfield, Va. 22151

In Response to:
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Project Officer

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16. ABSTRACT

The U.S. Environmental Protection Agency (EPA) is expanding its efforts to promote waste minimization activity in the private sector by providing technical assistance to generators of hazardous waste. As part of this effort, the EPA Office of Research and Development/Hazardous Waste Engineering Research Laboratory (ORD/HWERL), Cincinnati, Ohio, is promoting the developing ~~and testing~~ of a generalized or model waste minimization audit (WMA) procedure and test this procedure in actual production facilities agreeing to cooperate with the audit teams selected for this task.

In ~~this~~ report, results are presented of WMAs conducted at generators of corrosive heavy metals wastes. A specialty steel manufacturing complex employing electric arc furnaces (EAFs) for the manufacture of stainless and electrical steels, hot and cold rolling facilities for fabrication of the various steel grades into strip, and annealing and pickling facilities for finishing the strip, agreed to provide host facilities for the WMA effort reported herein.

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments and the needs of both large and small businesses in handling their wastes responsibly and economically.

This report describes several studies carried out to identify waste minimization opportunities for hazardous waste reduction. It will be useful to individuals interested in hazardous waste minimization technology and technologies.

For further information, please contact the Alternative Technologies Division of the Hazardous Waste Engineering Research Laboratory.

Thomas R. Hauser
Director
Hazardous Waste Engineering Research Laboratory

ABSTRACT

The USEPA is encouraging hazardous waste generators to develop programs to reduce the generation of hazardous waste. To encourage such programs the Agency's Hazardous Waste Engineering Research Laboratory is supporting the development and evaluation of a model hazardous waste minimization audit procedure. The procedure was tested in several facilities in the summer of 1986.

Waste minimization audits (WMAs) have been carried out in an electric arc furnace (EAF) specialty steelmaking complex. These audits were intended to develop waste minimization options for two hazardous waste streams at this facility: corrosive waste and heavy metals waste. Waste minimization options considered were in one of three categories: source reduction, recycling or treatment (in the same order of preference).

Application of WMA methodology to a corrosive waste stream (K062) generated at one plant in this complex, resulted in the development of a promising recycling option for the recovery of calcium fluoride (fluorspar) which is directly usable as a metallurgical flux (replacing presently purchased material) in the EAF steelmaking process at this facility. Savings obtained by using this option (including $68,000 savings from a thirty percent reduction in offsite nonhazardous waste disposal, and $100,000 savings in purchased chemical costs) were estimated at $168,000 annually, and the proposed process could largely use existing process equipment.

Application of the WMA methodology to a heavy metals-bearing waste (EAF dust-listed waste K061) generated at another plant in the steelmaking complex did not result in any viable source reduction or recycling options for this waste. However, a detoxification treatment step proposed for this material is economically attractive based on preliminary estimates, and bench-scale development of this option appears warranted.

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SECTION 1

INTRODUCTION

The national policy objectives established under the 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act of 1976 include the goal of reducing or eliminating hazardous waste as expeditiously as possible. To promote waste minimization activities, the Hazardous Waste Engineering Research Laboratory (HWERL) of the U.S. Environmental Protection Agency (EPA), Office of Research and Development, has undertaken a project to develop and test a waste minimization audit (WMA) procedure. It is envisioned that such a procedure would be useful to generators of hazardous waste as they search for waste minimization alternatives.

A number of authors have recognized the potential value and desirability of conducting waste audits, although they have suggested differing approaches and scope limits for such audit activities (U.S. Congress 1986, USEPA 1986a, Fromm and Callahan 1986, Pojasek 1986, Kahane 1986, League of Women Voters, Mass. 1986). This HWERL project tests a recently developed audit procedure by conducting actual audits in cooperating industrial and government facilities. To complete this project, seven audits were carried out in seven different facilities. Three of these audits are presented in this report, while the remainder are discussed in two companion reports. The proposed audit procedure has been modified somewhat to reflect the insights and experience gained in this field work.

Section 2 of this report presents the elements of an overall waste minimization program, of which the audit procedure is an important component. Section 3 describes with the WMA procedure, its development, and its final recommended form. Section 4 presents the results of the WMAs performed at facilities with steel pickling operations that generate corrosives-bearing waste, and Section 5 contains the results of the WMA performed at an electric arc furnace steelmaking operation generating heavy metals waste.

SECTION 2

WASTE MINIMIZATION PROGRAM

Structured programs designed to improve the cost, energy efficiency, safety, and other environmental aspects of an industrial undertaking are not a new concept. During World War II, the General Electric Corporation developed standardized procurement procedures for reducing product cost without sacrificing functionality. Later, similar procedures were developed and applied to lower the costs of design and construction projects. This activity, known as value management, value engineering, or value analysis, is currently a well established government requirement. In fact, it was mandated by the U.S.EPA for all construction projects involving wastewater treatment plants. A subsequent study of 156 treatment plants showed that cost reduction programs saved $95 million, or a 12 to 1 return on investment (Zimmerman and Hart 1982).

Environmental compliance audits and reviews are also becoming more common and are acquiring the status of an industry norm. The primary objective of an environmental audit is to determine the status of a corporation's compliance with Federal, State, and local environmental laws and regulations (Truitt et al. 1983). Additionally, such audits often can provide information to aid risk assessment and corporate planning.

Energy conservation audits are performed to reduce energy consumption per unit production. It was estimated that energy audits helped save chemical process industries about $1 billion between 1974 and 1979 (Parkinson 1979). Other related structured programs include safety reviews, hazard analyses, or failure mode and effects analyses. Waste minimization programs can be considered to be in the same category as these programs.

The principal objective of a waste minimization (WM) program is to reduce the quantity and/or toxicity of waste effluents leaving the production process in a manner consistent with the goals of protecting human health and environment. Unlike environmental audit programs, a WM

program does not seek to determine or improve the regulatory compliance status of a facility. Rather, it is primarily oriented toward producing a set of effective measures to reduce waste generation.

Table 1 presents a breakdown of WM program elements. In the context of an overall WM program, the waste auditing process (composed of pre-audit, audit, and post-audit phases) follows the program initiation/planning phase. During this initiation/planning phase, the commitment of top management to reduce waste generation must first be established. This is often done with a formal directive signed by the chief executive officer of the firm or an administrator of a government organization. The organizational commitment to start a WM program is often associated with a goal setting process, e.g., duPont is considering an annual 5 percent waste reduction goal (Government Institutes 1986).

A corporate WM program may be organized in a typical pyramid structure, with command and monitoring functions centered at the corporate level and implementation responsibility totally delegated to individual plants. A corporate-level independent expert task force may be formed to assist individual plants in setting up and executing their own WM programs.

At the plant level, the WM program may follow the scheme successfully used at Union Carbide for energy conservation efforts. At Union Carbide plants, a plant program coordinator is appointed and supported by a committee. The coordinator then selects and oversees individuals in each department who are responsible for devising and/or carrying out WM activities in their departments (Williams 1976).

This program planning phase should include the selection of audit team(s) to carry out the next program phase. The audit team leader should have a strong technical background, demonstrated problem solving ability, and, if possible, experience associated with the relevant process(es). In addition, the leader should possess strong management and communication skills. It would be preferable for the leader, or at least some members of the audit team, to have no previous association with the plant, so as to bring a fresh and unbiased perspective to the audit process. Such outsiders can be independent consultants or qualified personnel from other plants.

The audit team must have access to all required documentation and to a wide variety of plant personnel. During a recent internal workshop on waste minimization conducted by a major U.S. corporation, the participants (mostly environmental affairs managers at individual plants) were asked who should provide support to a waste audit team (Westinghouse Electric Corporation 1986). The following responses were obtained:

TABLE 1. WASTE MINIMIZATION PROGRAM ELEMENTS

Program phase	Job plan* phase	Elements
I. Initiation/ Planning		• Secure commitment/authority
		• Establish goals
		• Establish organization
II. Pre-Audit	Information	• Preparation for the audit
		• Pre-audit inspection
		• Waste stream selection
III. Audit	Creative	• Facility inspection
		• Generate comprehensive set of WM options
	Judgment	• Options evaluation
		• Selection of options for feasibility analysis
IV. Post-Audit	Development	• Technical and economic feasibility analysis
	Recommendation	• Report preparation
V. Implementation		• Selection of options for implementation
		• Design, procurement, construction
		• Startup
		• Performance monitoring

* Term adopted from value management program.

- Raw material suppliers;
- QA/QC department;
- Outside consultants;
- Customer representatives;
- Process engineer;
- Safety engineer;
- Materials engineer;
- Foreman;
- Plant manager; and
- Purchasing agent.

In short, the organization should be prepared to provide the audit team with access to a wide range of people both inside and outside the firm. The teams that carried out the audits described in this report were composed entirely of employees from outside consulting/engineering firms. Table 2 depicts the composition of the outside audit teams and the resident support groups.

The waste minimization auditing process (Table 1, phases II, III, and IV), which is described in detail in the next section, provides the key input to the implementation phase of the program, i.e., recommendations on which WM measures are to be implemented. Once a decision is made to proceed with the implementation of a specific WM measure, subsequent activities follow a well established, conventional pattern. Detailed design follows preliminary design; the procurement effort proceeds from inquiry and definitive bids to bid analysis and the expediting stages; and construction advances along the path determined by a detailed schedule and budget. The budget is controlled through estimates of cost performed at various project stages; accuracy increases as material and labor requirements become better defined. Startup follows mechanical completion. Finally, to ascertain the effectiveness of the changes made, ongoing performance monitoring is undertaken.

TABLE 2. WASTE AUDIT TEAMS AND RESIDENT SUPPORT GROUPS FOR THE THREE AUDITS AT CORROSIVE AND HEAVY METALS WASTE GENERATING FACILITIES

Plants No. 1 and 2 (Steel Pickling Facilities)

1. Outside Audit Team

   Chemical engineer*, Ph.D., 37 yrs of experience

   Physical chemist, M.S., 20 yrs of experience

   Independent consultant**, Ph.D., Chemistry, 25 yrs of experience in environmental engineering

2. Resident Support Team

   Plant environmental coordinator

   Plant environmental engineer

   Company main office staff environmental engineer

Plant No. 3 (EAF Steelmaking Melt Shop)

1. Audit Team

   Chemical engineer*, Ph.D., 37 yrs of experience

   Physical chemist, M.S., 20 yrs of experience

   Independent consultant**, Ph.D., Metallurgical Engineering, 40 yrs of experience in metallurgy, process and environmental engineering

2. Resident Support Team

   Plant environmental coordinator

   Plant environmental engineer

   Company main office staff environmental engineer

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* Audit team leader.

** Technical support and review function only.

SECTION 3

WASTE AUDITING METHODOLOGY

As was shown in Table 1, waste minimization audits are a central feature of a WM program. The auditing process is subdivided into pre-audit, audit, and post-audit phases. The recommended sequence of steps shown in Table 1 (also shown in expanded form in Table 4), is based on modifications of the originally proposed sequence, which is presented in Table 3. Modifications were made to reflect the experience and insights gained as a result of actual audit work. The following sections detail each of the eight sequential steps of the recommended waste minimization audit (WMA) procedure shown in Table 4.

PREPARATION FOR THE AUDIT

The objective of this activity is to gain background information about the facility to be audited. Preparation should include examination of literature references related to the activities performed at the facility, such as EPA background documents on the industries involved, plant permit applications, and other relevant documents pertaining to waste discharge at the industrial facilities of interest. Proper preparation should result in a well-defined needs list, inspection agenda, or a checklist detailing what is to be accomplished, what questions or issues need to be resolved, and what information should be gathered.

For the host facilities audited in this report, the needs list (Table 5) was provided to the resident support team in advance of the site visit. This was very important in ensuring the success (and efficiency) of the site visit, since it provided time for the facility personnel to assemble the materials needed by the audit team prior to its visit. A more generalized list of documents and information sources is given in Table 6.

In the audits of the three facilities reported herein, the availability of the required process documentation was excellent. This documentation proved to be invaluable in enabling the audit team to establish a set of waste minimization options.

TABLE 3. INITIALLY PROPOSED WASTE MINIMIZATION AUDIT PROCEDURE

Job plan element	Step
Information phase	1. Preparation for inspection
	2. Facility inspection
	3. Process and waste stream description
Creative phase	4. Generation of WM options
Judgment phase	5. Preliminary evaluation and ranking of options
	6. Presentation, discussion, and joint review of options with plant personnel
	7. Selection of options for feasibility analysis
Development phase	8. Technical and economic feasibility analysis
Recommendation phase	9. Final report preparation

TABLE 4. RECOMMENDED WASTE MINIMIZATION AUDIT PROCEDURE

Program phase	Activities	Product
Pre-Audit	1. Preparation for the audit	• needs list/ inspection agenda
	2. Pre-audit meeting and inspection	• notes
	3. Waste stream selection	• process description
		• waste descripton with rationale for selection
Audit	4. Audit inspection	• notes
	5. Generation of a comprehensive set of WM options	• list of proposed options with written rationale
	6. Options evaluation and selection for feasibility analysis	• list of selected options
		• options ratings by audit team and by plant personnel
		• options interim report
Post-Audit	7. Technical and economic feasibility analysis	• study or budget grade estimates of capital and operating costs; profitability analysis
	8. Final report preparation	• final report with recommendations

TABLE 5. WASTE MINIMIZATION AUDITS - INFORMATION NEEDS LIST FOR CORROSIVES AND HEAVY METALS WASTE STREAMS AT PLANTS NO. 1, 2, and 3

1. Process Flow Diagrams (PFDs) with Heat and Material Balances (HMBs).
2. Piping and Instrumentation Diagrams (P&IDs).
3. Plot plan or general arrangement of equipment.
4. Process description (process flows, liquid and solid wastes characterizations).
5. Equipment layouts (plan and elevation views).
6. Quantities and costs of chemicals.
7. Dimensions and operating gallonage of all pertinent process vessels and tankage.
8. Quantities and costs of disposal for all wastes, liquid and solid; frequency of pickling bath replacement.
9. Materials of construction.
10. History of previous waste management projects and any related documentation.

TABLE 6. WASTE MINIMIZATION AUDITS GENERALIZED LIST OF INFORMATION SOURCES

- Design process flow diagrams (PFD) with heat and material balances (HMB) for process and pollution control systems
- Equipment list
- Piping and instrument diagrams (P&ID)
- Materials application diagrams (MAD)
- Plot and elevation plans
- General arrangement drawings
- Piping layout drawings
- Operation manuals, process descriptions
- Permits and/or permit applications
- Emission inventories
- Hazardous waste manifests
- Annual (or biennial) reports
- Waste assays
- Operator data logs, batch sheets
- Materials purchase orders
- Environmental audit/review reports
- Production schedules
- Organization chart

Experience with other sites indicates that the availability and quality of information varies significantly, however. It is important to allow for this contingency and to have a fall-back position. For example, if a piping and instrument diagram (P&ID) is not available, it may be possible to obtain a piping layout plan instead. Similarly, if the information cannot be obtained from the facility, that does not mean that it is unavailable elsewhere. Much information is obtainable from outside vendors, e.g., the costs of bath make-up chemicals or the physical design of the process equipment. If information is truly needed, it can be obtained with proper initiative and ingenuity, although such action may affect project costs and schedules. In light of this possibility, it is important to seek only that information which is necessary to understand the process, to allow for delineation of waste sources and current waste management techniques, and to characterize waste generation quantitatively. Requesting unnecessary information burdens both the provider and user (auditor) and slows down the work.

HOST SITE PRE-AUDIT SITE VISIT

The purpose of this meeting is to become familiar with plant operations and plant personnel. Initial contacts with plant personnel should include solicitation of their views on the focus and function of the audit. This will help to identify waste streams of concern to the facility. The information needs defined in the previous step should be discussed here and hopefully met. A guided tour of the facility should be taken.

At this initial visit, the groundwork for a successful working relationship with facility personnel must be laid. It should be stressed that a cooperative attitude and active involvement by host facility personnel are essential to the success of the audit process. The initial point of contact at the facility (Plant Manager, Environmental Coordinator, etc.) must be enlisted as a "Product Champion" for the program before the audit commences. He/she must be encouraged to relay the message of cooperation and involvement to others at the facility.

WASTE STREAM SELECTION

Suitable waste streams should be selected either following the initial conference with plant personnel or after the first plant inspection. Selection should be based on discussions with plant personnel and on the independent assessment of the project team. The criteria used to select a waste stream must include at a minimum:

- Composition;
- Quantity;
- Degree of hazard (toxicity, flammability, corrosivity);

- Method and cost of disposal;
- Potential for minimization and recycle; and
- Compliance status.

For the three case studies cited in this report, stream selection was not a problem. Focusing the audits on two particular wastes (corrosives and heavy metals) simplified the selection. In the case of corrosives, steel pickling is the only corrosives waste producing operation that occurs at the audited facilities. The only heavy metals waste producing operation found at the audited facility is electric arc furnace steelmaking, which generates an exhaust dust containing significant quantities of hazardous heavy metals.

With the selection of the waste streams, the pre-audit stage of the procedure is completed. At this point, it is recommended that a written description be prepared of the facility, process, or operation and of the waste streams. The description should encompass:

- Facility location and size;
- Description of operations or processes of concern, including diagrams necessary to detail the pertinent aspects of waste generation;
- Waste stream(s) description centering on sources and current methods of management; this information should be supplemented with summaries of generation rates, compositions, disposal costs, and raw material costs, and the rationale for waste selection should be provided.

Descriptions of facility, process, and waste stream(s) for the facilities involved with corrosives and heavy metals audits are given in Sections 4 and 5. Such descriptions summarize all the pertinent information acquired.

HOST SITE WASTE MINIMIZATION AUDIT VISIT

In the course of the pre-audit activities, a general understanding of the process facility operations and, more important, of waste sources was established. Also, waste stream selection had been finalized (in most cases) and the information summarized in a written description of the facility, process, and waste stream(s).

With the needed comprehension of the process and focus in place, the audit inspection can now be conducted. Typically, the inspection would focus on selected aspects of the operation identified through the pre-audit activities. The governing objective is to obtain a greater awareness of the principal and secondary causes of waste generation and to examine the items overlooked in the pre-audit stage.

The audit inspection is the ultimate step in the information gathering process. The following guidelines have been formulated as a result of the work performed on this project:

1. Have an agenda ready. This should cover all points that still require clarification following the pre-audit phase.

2. Plan on inspection of the various process operations of interest at different times during the production shift for continuous processes such as acid pickling, in order to observe possible fluctuations in normally steady state operations. Expect to monitor operations over a period of one to two days.

3. Obtain permission to interview the operators, eight-hour shift supervisors, and foremen directly. Listen attentively and do not hesitate to question more than one person if the answer is not forthcoming. Try to assess the operators' and their supervisors' awareness of waste generation aspects of the operation. Note their familiarity (or the lack thereof) with the impacts their operation may have on other operations, e.g., the effect of dumping slugs of spent pickling acids into the existing wastewater treatment plant, rather than metering these solutions at a controlled rate.

4. Obtain permission to photograph the facility. Photographs are especially valuable in the absence of plan layout drawings. Many details can be captured in photographs that otherwise could well be forgotten or inaccurately recalled at a later date.

5. Observe the "housekeeping" aspect of the operation. Check for signs of spills or leaks. Ask to visit the maintenance shop and inquire about their problems in maintaining the equipment leak-free. Assess the overall cleanliness and order of the site.

6. Assess the level of coordination of environmental activities among various departments.

During the planning stage and the actual audit inspection itself, it is beneficial to mentally "walk the line" from the suspected source of waste generation to the point of exit, be it a treatment unit, storage facility, or haulage to offsite RCRA treatment, storage, and disposal (TSD) facilities. The audit inspection must result in a clear understanding of the causes of waste generation.

GENERATION OF WM OPTIONS

Thus far, the audit process has been mainly oriented toward information gathering and organization. These activities should have yielded a thorough understanding of the origins of waste generation and of the process or facility operations in general. The audit activity has now reached the creative phase.

The objective of this step is to generate a comprehensive set of WM options. Such activity may take the form of a "brainstorming" session involving audit team members or may involve separate efforts by individual members. A combination of these approaches was found to be of value during the audits conducted for this study. In this stage of the audit process, it is important to generate as many options as possible. Current WM measures in the audited facility should also be listed. This knowledge often leads to the formulation of additional options and provides valuable insights for the option evaluation step to follow.

In generating options, most of the effort should first focus on source reduction, followed by recycling and then treatment. Such a hierarchy of effort stems from the fact that environmental desirability favors source reduction over recycling and recycling over treatment.

Current EPA-proposed definitions of waste minimization and key waste minimization terms are given in Figure 3-1 A generalized guide map to various source reduction elements is shown in Figure 3-2 For a discussion of the terms and examples illustrating each element, the reader is referred to the EPA support document for the 1986 Report to Congress on Waste Minimization (USEPA 1986b).

To develop options, it is often necessary to examine the technical literature. The reference section of this report lists the sources consulted for steel industry-generated corrosives and heavy metals waste reduction, as well as sources used to support the theoretical basis for a corrosives waste recycle option. Options can also be formulated through discussion with manufacturers of equipment or suppliers of process input materials.

The result of the WM options generation step should be a list identifying each option, together with a brief description of the rationale for its listing. For the wastes studied in this report, only one relevant option could be determined at each of the facilities audited.

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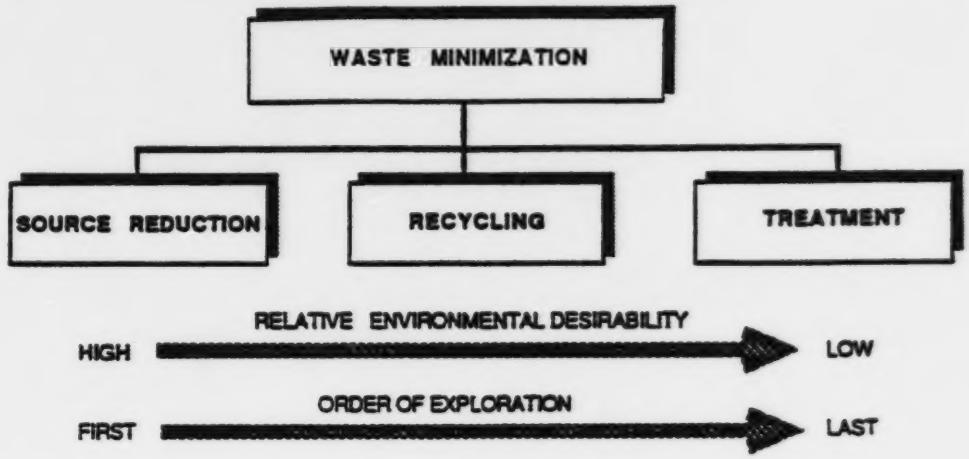

WASTE MINIMIZATION

The reduction to the extent feasible of hazardous waste that is generated or subsequently treated, stored or disposed of. It includes any source reduction or recycling activity undertaken by a generator that results in either (1) the reduction of total volume or quantity of hazardous waste or (2) the reduction of toxicity of the hazardous waste, or both, so long as such reduction is consistent with the goal of minimizing present and future threats to human health and environment (EPA's Report to Congress, 1986).

SOURCE REDUCTION

The reduction or elimination of waste generation at the source, usually within a process (op.cit).

RECYCLING

A material is "recycled" if it is used, reused, or reclaimed (40 CFR 261.1 (c) (7)). A material is "used or reused" if it is either (1) employed as an ingredient (including its use as an intermediate) to make a product; however a material will not satisfy this condition if distinct components of the material are recovered as separate end products (as when metals are recovered from metal containing secondary materials) or (2) employed in a particular function as an effective substitute for a commercial product (40 CFR 261.1 (c) (5)). A material is "reclaimed" if it is processed to recover a useful product or if it is regenerated. Examples of recovery of lead values from spent batteries and regeneration of spent solvents (40 CFR 261.1 (c) (4)).

TREATMENT

Any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste or so as to render such waste non-hazardous, safer for transport, amenable for recovery, amenable for storage or reduced in volume. Such term includes any activity or processing designed to change the physical form or chemical composition of hazardous waste so as to render it non-hazardous (RCRA, Subtitle A, Section 1004(34), PL-98-616).

Figure 3-1 Components of waste minimization, their hierarchy and definitions.

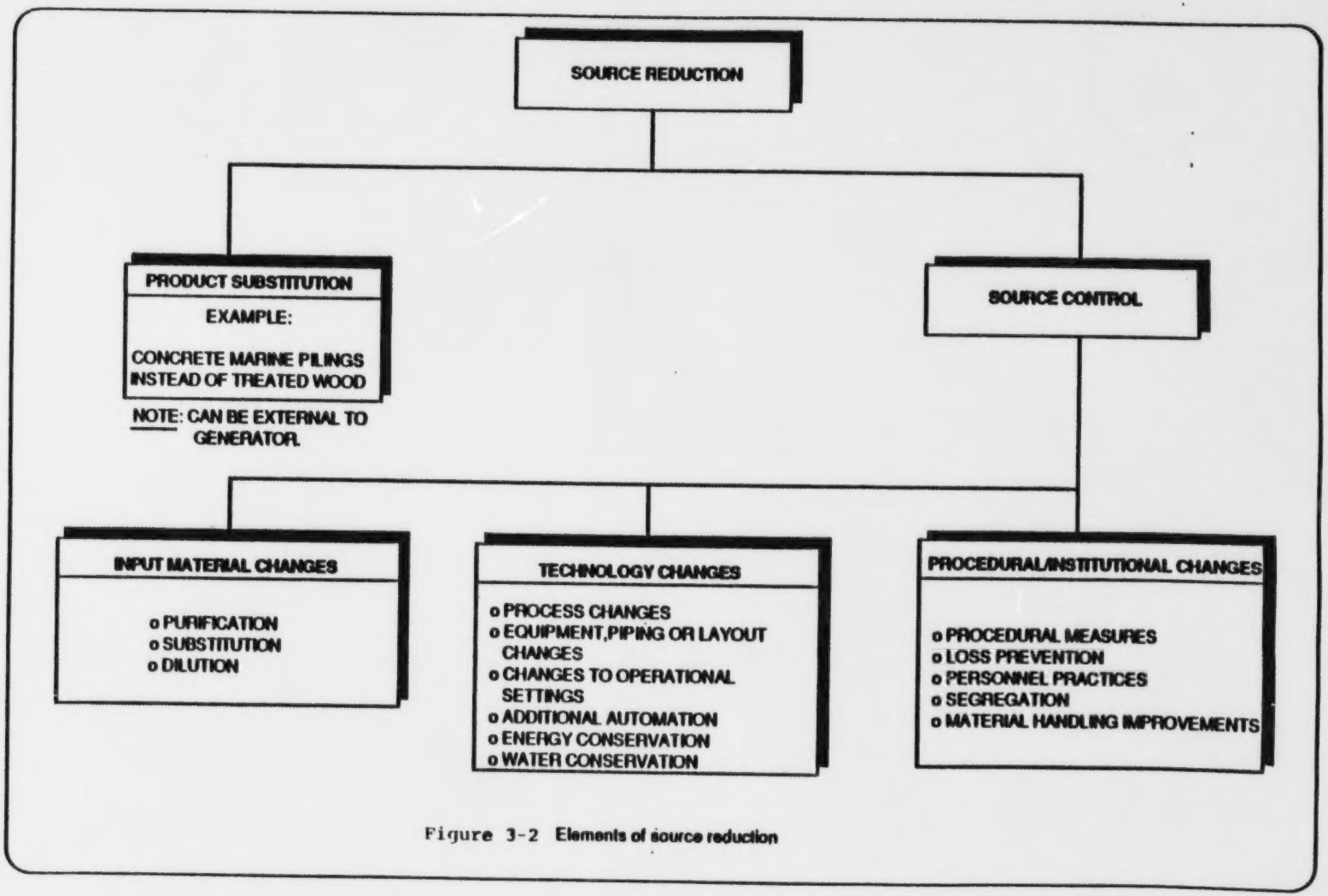

Figure 3-2 Elements of source reduction

PRELIMINARY EVALUATION AND RATING OF OPTIONS

Each of the options postulated in the preceding step must undergo a preliminary engineering evaluation and rating. The objective of this evaluation is to eliminate the measures that do not merit additional consideration and to rank the remaining measures in order relative to their overall desirability.

The evaluation should include, at a minimum, consideration of the following aspects:

- Waste reduction effectiveness (i.e., reduction of waste quantity and/or toxicity);
- Extent of current use in the facility;
- Industrial precedent;
- Technical soundness;
- Cost (preliminary capital and operating cost evaluation);
- Effect on product quality;
- Effect on plant operations;
- Implementation period; and
- Resources availability and requirement.

The preliminary evaluation and valuing process would consist of the following steps carried out by the audit team:

(a) Developing a written rationale for each proposed option including a clear description of the operating principle, estimates of waste minimization measured in pounds of waste and in pounds of waste per unit production, estimates of potential resource recovery measured in pounds of waste component recyclable to the process or salable as a recovered material, perceived advantages and disadvantages, simplified schematics of the proposed material flow, material balance calculations, "order of magnitude" cost estimates, references relating to prior applications, and other relevant documentation pertaining to the idea. These operations were carried out for each option developed for the corrosives and heavy metals waste streams studied.

(b) Qualitative rating of each option in three categories: waste reduction effectiveness, extent of current use, and future application potential. The ratings are to be done on scale of 0 to 10 by a proponent, then reviewed by the audit team leader.

It is expected that some options may receive ratings low enough to warrant their withdrawal. The team leader may call a review meeting to submit the ratings to a collective discussion or vote. In the case of the audits discussed in this report, a number of such options were withdrawn, as is discussed in Sections 4 and 5.

The product of this effort should be a table summarizing the preliminary ratings for each option that addresses a particular waste stream or source, along with the written documentation developed in this phase of the audit. Table 7 is a sample table illustrating the approach used to develop such a summary table.

PRESENTATION AND JOINT REVIEW OF OPTIONS WITH PLANT PERSONNEL

Following the technical and economic evaluations of the selected options by the audit team, these options are prepared in the form of a Preliminary Audit Report to be submitted to appropriate plant personnel. Each option in the Preliminary Audit Report should be well described in terms of the technical rationale and projected "order of magnitude" cost estimates. Cost estimates are of particular importance to plant personnel who have to deal with tight operating budgets and must have some idea of the cost of implementing an attractive-appearing option. In this regard, calculation of "the payback period" will provide a quick indication of the economic viability of the proposed option. Cost estimates are also of importance to the options belonging to the category of good operating practices. Availability of preliminary cost data along with the presentation of this category of option circumvents quick dismissal of these options as "trivial" by a technology-oriented plant engineer.

The plant personnel should then be asked to review the Preliminary Audit Report and independently rate each proposed option, revise them based on their assessment, and incorporate any additional options they consider applicable.

The review process would culminate in a joint meeting in which the audit team would present the proposed options one by one. The presentation ideally should include a detailed discussion of the rationale and reasons for selected ratings. The plant engineers would then present their critique or comments. The discussion should conclude with a revised rating acceptable to both sides. If such a conclusion cannot be reached, a further course of action must be well outlined.

Table 7. SUMMARY OF SOURCE CONTROL METHODOLOGY FOR THE A/B POWDER FORMULATION PROCESS ILLUSTRATION OF DEVELOPMENT OF OPTIONS RANKING

Waste source	Control methodology	Waste reduction effectiveness	Extent of current use	Future application potential	Fraction of total waste	Current reduction index	Future reduction index
Weighing operation	1. Return empty containers	2	0	2		0.00	0.25
	2. Use preweighed containers	2	0	4		0.00	0.50
	3. Use drum covers	2	2	1		0.25	0.06
	Overall	2.00	0.67	2.33	0.10	0.25	0.50
Wet grind loading and unloading	1. Use plastic funnel/collar on unit	2	0	4		0.00	0.50
	2. Use smaller trays, manual operation	2	0	2		0.00	0.25
	3. Place trays on rack, walk-in oven	2	0	2		0.00	0.25
	4. Use elevator table on rack, walk-in oven	1	0	1		0.00	0.06
	5. Install roller conveyer under valve	1	0	1		0.00	0.06
	6. Install fail-close valve on discharge	2	0	3		0.00	0.38
	7. Pump slurry into trays over at oven	2	0	1		0.00	0.13
	8. Reduce cleaning frequency	3	0	3		0.00	0.56
	9. Bypass dry grinding unit	2	0	4		0.00	0.50
	Overall	1.89	0.00	2.33	0.45	0.00	0.56
Dry grind loading and unloading	1. Use plastic funnel/collar on unit	2	0	4		0.00	0.50
	2. Do not load while unit is operating	3	4	0		0.75	0.00
	3. Inspect all seals regularly	2	3	2		0.38	0.06
	4. Use drum covers	2	2	3		0.25	0.19
	5. Bypass dry grinding unit	4	0	4		0.00	0.90
	Overall	2.60	1.80	2.60	0.45	0.75	0.90
All sources	All methods				1.00	0.58	0.71

The objective of the meeting is to obtain an agreement on the ratings of various proposed options; these ratings would then be analyzed and used to rank all the options, with the aim of selecting those that warrant further evaluation by the plant. It also may happen that the plant personnel may suggest new options or that such options may result from the joint discussion.

Following the meeting, all appropriate revisions of the options presented in the Preliminary Audit Report would be made in preparation for the issuance of a Final Audit Report.

In the present audit effort, both the audit team and the plant personnel were in agreement on the evaluation of each of the options presented.

FINAL AUDIT REPORT

In accordance with the workplan, the Final Audit Report will contain, at a minimum, the following sections:

1. Facility and process description;

2. Description of waste stream(s) origin, composition, and quantities;

3. Detailed description of all work minimization options considered, including simplified schematics of revised process flows (if appropriate) and lists of any new process equipment required;

4. Detailed evaluation of technical feasibility and potential benefits of all waste minimization options considered, together with their preliminary economics (capital and operating costs, estimated payback period) and final rankings (based on audit team findings and host plant engineers evaluations); and

5. Recommendations including any research and development efforts needed to further evaluate the recommended options.

WASTE AUDITING - SOME DO'S AND DON'TS

Some of the most important lessons learned in the pilot audits relate to the human element of the audit process, i.e., to the interaction between the audit team and the host facility personnel.

Obviously it is vital that host facility personnel become and remain active participants throughout the audit process. Some non-technical skills of the audit team personnel, and particularly of the audit team leader, were found to be extremely valuable here.

The audit team leader must be an effective and aggressive communicator as well as a technical expert, because this individual must serve as a facilitator for the audit team and host facility personnel alike. A reserved and low key attitude and behavioral style by the audit team could lead to a passive or disinterested stance by the host facility personnel.

The experience gained in these audits also led to a modification of the audit method. The modified approach requires host facility personnel to independently develop ratings for each of the waste reduction options under consideration. The audit team's ratings for the options and the host facility's independent ratings can then be reviewed and reconciled in a group session. The initial approach of having the host facility personnel merely review and discuss the audit team's ratings following the presentation of the option ratings resulted in relatively casual, uninvolved behavior by the host facility staff.

The pre-audit activities, particularly the pre-audit site visits, were found to be extremely important in facilitating the audit process. When the audit team spent a little more time getting to know the host facility staff and the functioning of the organization, the audit process moved more smoothly. The audit team found it easier and faster to acquire needed data because the members knew the operation and the people a little better, and the level of cooperation by plant staff was improved.

In summary, a WMA (and a WM program as a whole) requires that audit team members exhibit effective communications and human interaction skills, as well as technical insight and engineering ability. A successful WM audit program thus requires success in both technical and human relations areas.

SECTION 4

CORROSIVE WASTES - WMA CASE STUDIES

Two facilities were selected as host sites for WMAs at industrial generators of corrosive waste. The two plants involved are located at an electric arc furnace (EAF) steelmaking complex in the East. Background information on corrosive waste generation at this steelmaking complex was available in an EPA Effluent Guidelines Development Document (EPA 1980). In this report, these plants are designated as Plant No. 1 and Plant No. 2.

WMA AT PLANT NO. 1

Facility Description

The Plant No. 1 facility consists of a stainless steel strip annealing and pickling line for processing of 300 and 400 series stainless steels and a pickling wastewater neutralization plant.

Process Description

The Plant No. 1 pickling line pickles only stainless steels and is composed of (1) a Kolene treatment tank where the annealed steel sheet is treated with Kolene (a mixture of molten sodium hydroxide and potassium hydroxide) for descaling, (2) a Kolene quench tank, (3) two water rinse tanks in series, (4) a nitric-hydrofluoric acid pickling tank, (5) a final rinse tank, and (6) a fume scrubber. A simplified schematic of the line is shown in Figure 3.

In the operation of the facility, 300 and 400 grades of stainless steel strip are received from the main EAF steelmaking facility,* located about 2 miles from Plant No. 1. The stainless steel strip is first annealed and then descaled by the Kolene treatment in which oxide scale

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*Designated as Plant No. 3 in this report.

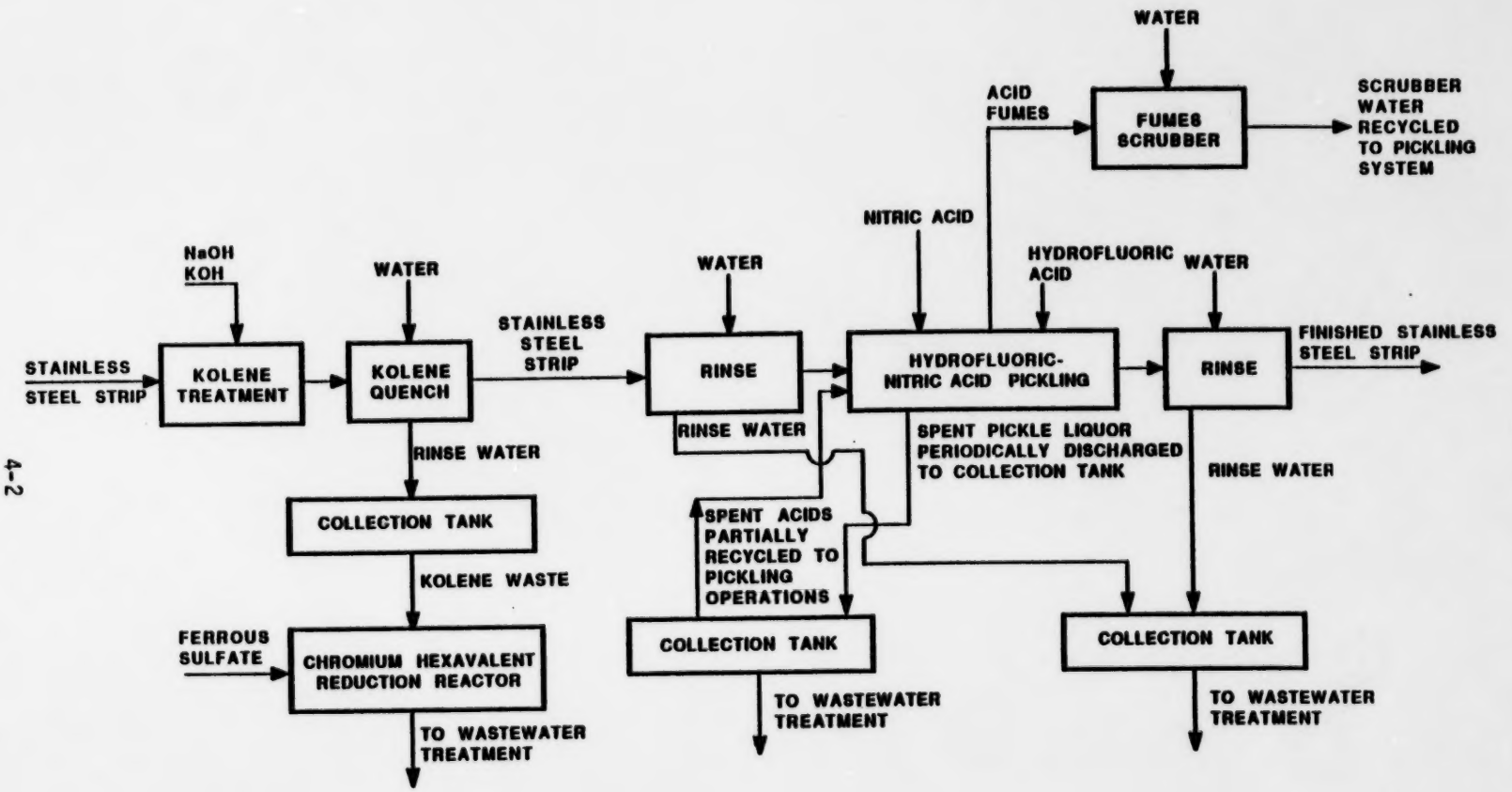

Figure 3. Simplified Schematic Of Existing Stainless Steel Surface Treatment And Pickling Processes - Plant No. 1.

is removed by molten NaOH/KOH treatment at 800°F. The descaled sheet is then rinsed to remove caustic materials and passed through a pickling operation where it is treated with a solution consisting of 2 to 4 percent hydrofluoric acid and 8 to 10 percent nitric acid. The pickled steel strip is then rinsed and coiled for shipment. The air emissions from the Kolene treatment and pickling acid tanks are all controlled by the use of fume scrubbers.

Waste Stream Descriptions

There are two corrosive waste streams generated by the operations at Plant No. 1:

- The Kolene rinse water is highly alkaline and contains sodium and potassium hydroxides, sodium and potassium carbonates, and chromates resulting from some oxidation of the chromium on the steel surface during the Kolene descaling treatment. Chromate levels are below 200 ppm, and the spent rinse water has a pH of about 12.

- Spent pickle liquors and rinse waters from the pickling operations have a pH of about 2 and contain dissolved metals, nitrate, and fluoride. Approximately once per week, spent pickling acids (HF and HNO_3) are drained from the pickling tub, fresh acids are added, and a portion of the dumped spent acid is recycled. The spent pickle liquors contain 0 to 2 percent hydrofluoric acid and 0 to 8 percent nitric acid. They also contain dissolved nitrates and fluorides of cadmium, nickel, chromium, and iron. The excess spent pickle liquor is combined with the pickling line rinse water prior to being sent to the wastewater treatment facility. Average composition of the spent pickle liquor/rinse water stream over a one-week operation (which includes a once-per-week dump of the spent pickle liquor into the combined wastewater stream) is given as:

Parameter	Average concentration, mg/l
Cr (trivalent)	164
Ni	47
Cd	<0.02
Fe	1,110
F	1,100
pH	~2.0

Volumes of wastes generated are as follows:

- About 5,000 gallons per week of the spent HF/HNO_3 pickle liquor are disposed of.

- The combined wastewater stream from pickling operations, including rinse waters and spent pickling acids, averages 150 gallons per minute.

- Approximately 45 gpm of alkaline Kolene process rinse water are treated and disposed of.

Current Waste Treatment Practice

The Kolene waste rinse water and the combined spent acid/rinse water waste stream are treated as follows:

- Raw Kolene rinse water is treated in a mix tank with excess ferrous sulfate heptahydrate and sulfuric acid with about 80 minutes retention time. The ferrous ion reacts with chromate to reduce hexavalent chromium to trivalent chromium. The waste pH following treatment is approximately 4.

- The combined spent acid/rinse water waste and the treated Kolene rinse water are pumped to a mix tank where slaked lime is added. The final pH after lime addition is about 8. The addition of lime causes the heavy metals present to precipitate as hydroxides and the fluoride to precipitate as calcium fluoride. The resulting mixture of treated wastewater and precipitated solids is treated in a second mix tank where coagulant is added, and the stream is then fed to two 30-foot diameter clarifiers operated in parallel. The clear overflow from the clarifiers is discharged to the outfall (a local creek) meeting the conditions of an NPDES permit, and the underflow is fed to two vacuum filters operated in parallel. Nonhazardous solids recovered from the filters are disposed of off site, and the filtrate is recycled to the treatment process.

Figure 4 is a simplified schematic of the present Plant No. 1 wastewater treatment system.

Postulated Waste Minimization Options

During the formal audit phase of this study at the Plant No. 1 acid pickling facility, process and waste treatment operations were intensively studied by the audit team. The use of various potential source reduction and resource recovery options was reviewed with plant personnel. In terms of source reduction, the plant already recycles part of the spent acid mixture to the pickling line, thus reducing fresh acid use. Based on the audit team's evaluation and discussions with plant personnel, there did not appear to be any other significant source reduction options available.

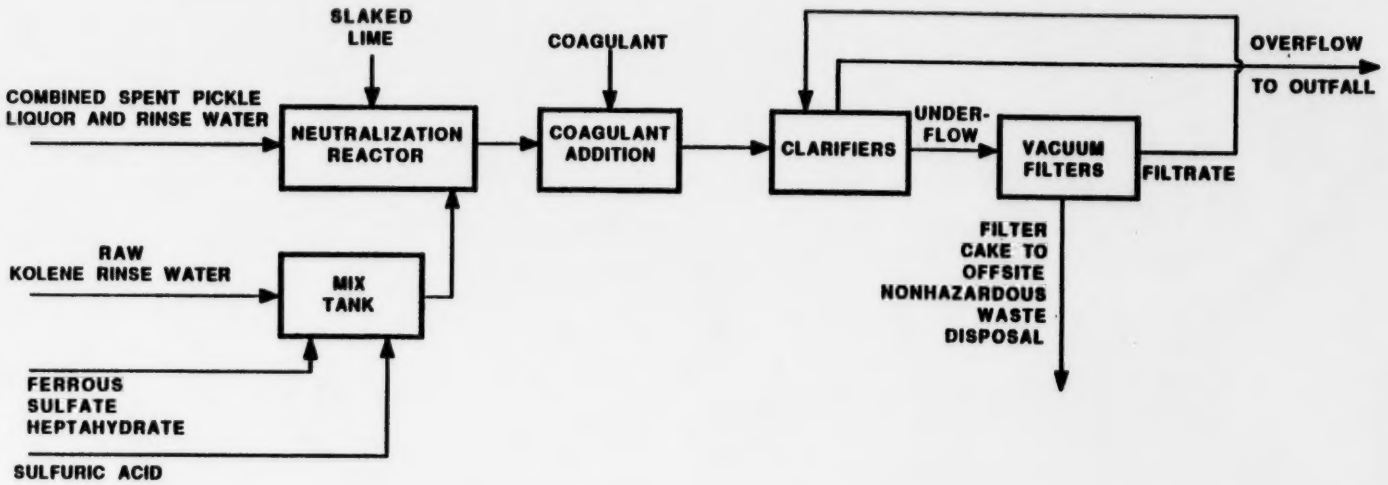

Figure 4. Simplified Schematic Of Present Wastewater Treatment System - Plant No. 1.

With respect to resource recovery, the present neutralization treatment of the combined Plant No. 1 pickling line wastewater stream (K062) generates a mixed sludge for which there is essentially no potential for reuse. The audit team determined that the raw waste, however, does contain a constituent (fluoride ion) that could be converted into a useful product--calcium fluoride (fluorspar). The EAF steelmaking facility at this location presently purchases about 1,000 tons per year of fluorspar for use as a furnace flux material in the steelmaking process. Current cost for metallurgical grade fluorspar (approximately 80 percent calcium fluoride) for flux use is $100 per ton at the plant. The audit team proposed a waste minimization option for recovery of calcium fluoride wherein the combined Plant No. 1 wastewater stream at pH ~2 (excluding the treated Kolene waste) is treated with slaked lime at a controlled rate so that pH ~2.5 is not exceeded. Calcium fluoride will precipitate selectively, and at this pH, fluoride solubility data as shown in Figure 5 (American Chemical Society 1958, Aumeras 1927) indicate that a level of 65 ppm dissolved fluoride may be achieved. With about 1,100 ppm dissolved fluoride in the raw wastewater, as much as 95 percent of the fluoride can be recovered. This is equivalent to about 1,100 tons per year of calcium fluoride potentially recoverable (based on 300 days per year operation), which more than equals the annual consumption of calcium fluoride (fluorspar flux) in the EAF operation. Hydroxides of iron, nickel, and chromium are all highly soluble at pH values below 3.0, and thus would not be expected to co-precipitate with the calcium fluoride.

If this calcium fluoride recovery option were to be put into operation at Plant No. 1, not only would the generation rate of sludge from K062 treatment be reduced (resulting in a saving in offsite sludge disposal costs),* but a substantial potential savings in chemical purchases could be made. Plant personnel agreed with the audit team that this was a worthwhile option.

Feasibility Analysis of the Selected Waste Minimization Option

After a resource recovery option had been established for the Plant No. 1 corrosive waste, the preliminary engineering design and cost estimate for this option was developed.

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* Plant No. 1 disposes of approximately 4,000 tons per year of nonhazardous sludge from the present wastewater treatment process (in an offsite landfill) at a cost of $228,000 per year. Although this cost would be expected to increase in subsequent years, the present study did not attempt to forecast this cost increase.

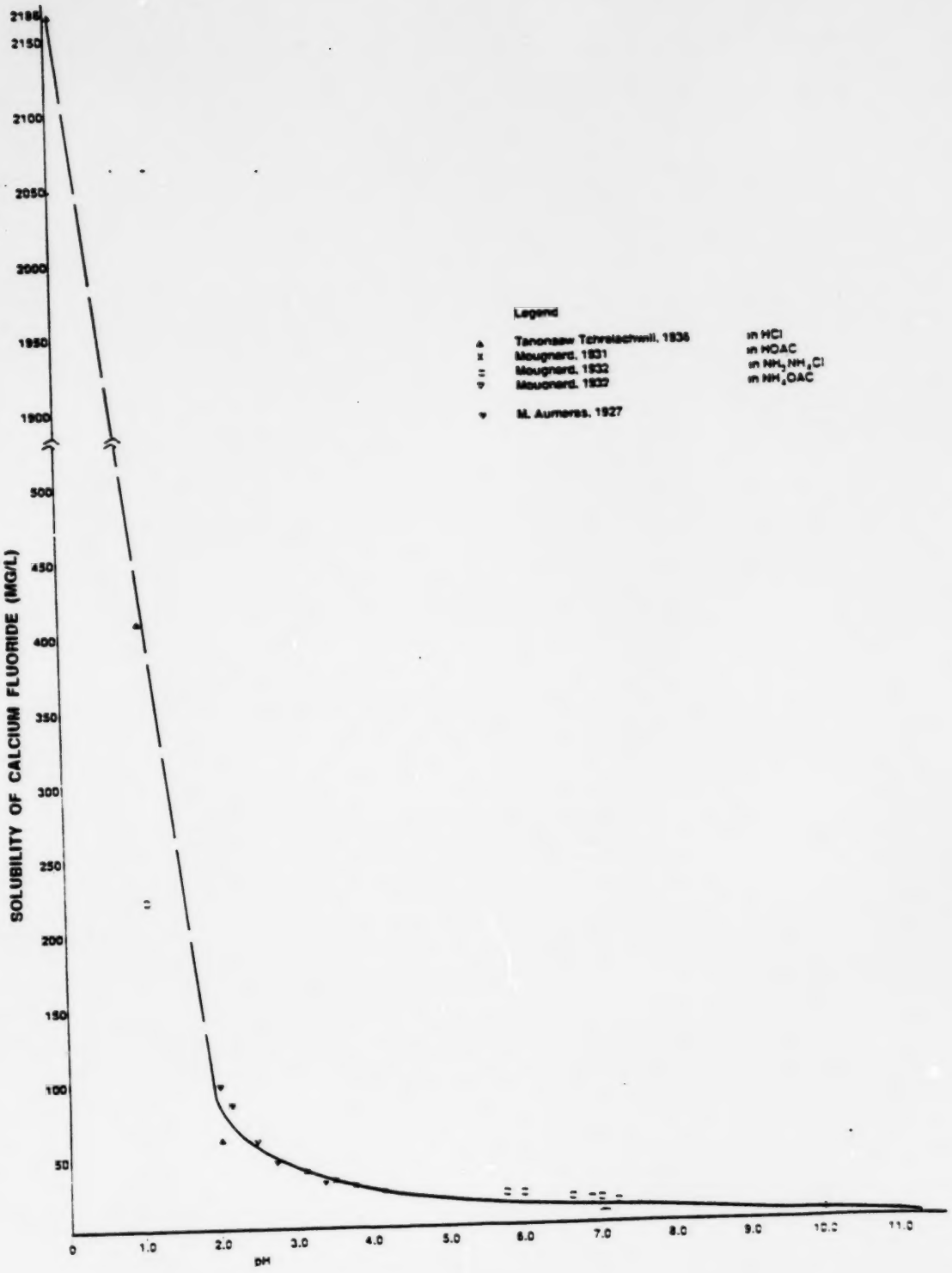

Figure 5. Solubility of Calcium Fluoride as a Function of pH.

The necessary process modifications needed to recover solid calcium fluoride are shown in simplified schematic form in Figure 6 and consist of the following:

- The combined spent pickle liquor and rinse water discharge would be treated in the same waste acid neutralization system now used to generate the neutralized nonhazardous solids discharged off site and the NPDES effluent discharged to the outfall. However, the neutralization would be done in series in two stages, thereby effecting the recovery of a reasonably pure calcium fluoride in the first stage. After the first stage of neutralization, the presently treated Kolene waste would be combined with the partially neutralized waste pickle liquor/rinse water stream. The combined stream would then be neutralized and discharged to the outfall.

- In the existing neutralization reactor, slaked lime would be added to the combined pickle liquor/rinse water stream containing 1,100 ppm of fluoride, at a rate controlled to achieve a pH no higher than 2.5. At this pH, precipitation of fairly pure calcium fluoride would occur at the rate of 400 to 500 lb/hr. This slurry (with added coagulant) would then flow to one of the existing 30-foot diameter clarifiers where, after about one hour's settling time, the underflow would flow to one of the two existing 6 ft x 6 ft vacuum belt filters. Following filtration, the filtered solids would be collected and after drying and

  briquetting, would be periodically transported to the EAF steelmaking melt shop for use as flux in place of purchased fluorspar.*

- The combined clarifier overflow, vacuum belt filter filtrate, and the separately treated Kolene waste would be pumped to the other existing 30-foot diameter clarifier where additional slaked lime and coagulant would be added to bring the final pH up to 8. At this pH, the residual fluoride and heavy metals would precipitate as calcium fluoride and hydroxides, respectively. The settled slurry would then flow to the second existing 6 ft x 6 ft vacuum belt filter, where the solids are removed and discharged. These

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* Because of space considerations, the drying and briquetting operations would probably be carried out in a suitable area near the EAF melt shop facility.

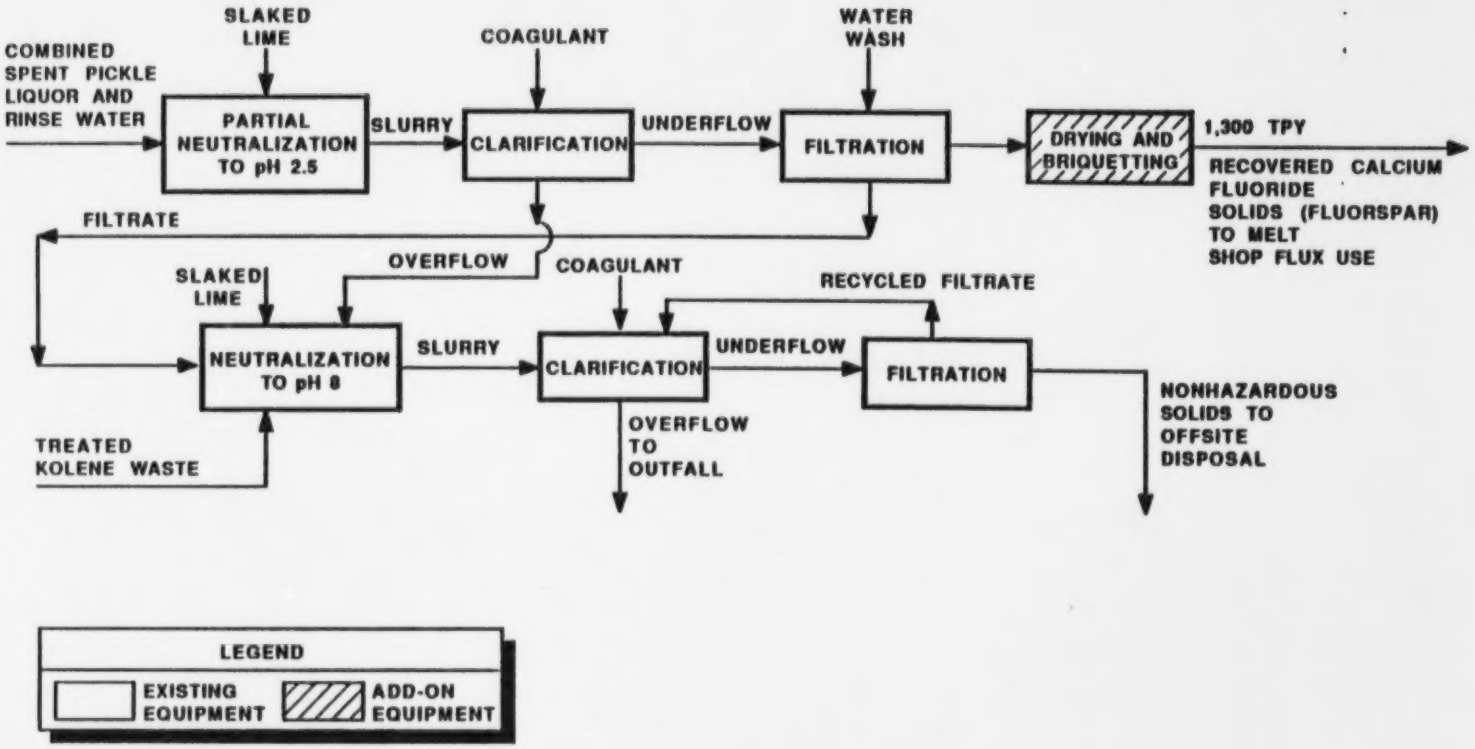

Figure 6. Proposed Alternative Treatment System For Recovery Of Calcium Fluoride From Combined Spent Acid Pickle Liquor And Rinsewater Plant No. 1.

solids are nonhazardous and are sent to offsite disposal. The solids tonnage sent to offsite disposal would be reduced by approximately 30 percent. The clarifier overflow is discharged to the local outfall.

- Based on discussions with plant personnel, it is believed that there is enough capacity available in the present clarifier/filter system at Plant No. 1 to allow the entire wastewater flow to proceed in series fashion through the two sets of clarifiers and filters. Retrofit of one clarifier (epoxy coating) and one vacuum filter (rubber covering of all exposed parts), as well as replacement of all interconnecting piping and valves with acid-resistant material, is required for operation in the pH 2.5 environment of the first selective precipitation stage.

The economic viability of this waste minimization option, based on preliminary capital and operating cost estimates, is discussed below. The capital cost estimate prepared at this time should be considered order of magnitude (±40 percent accuracy).

Capital Costs	Installed Cost, $
Capital Equipment Requirements:	
• Drying (indirect gas-fired rotary dryer) and briquetting equipment to process 6.1 TPD of precipitated calcium fluoride (30% moisture) equivalent to 4.3 TPD of dry, briquetted fluorspar equivalent.*	200,000
Existing Equipment Modifications:	
• Epoxy-coat one existing 30 ft diameter x 15 ft high carbon steel clarifier with 30 mil thickness of Bridgeport Chem. Corp. 6A70 (or equal) epoxy resin. Five-year warranty against liner failure. Complete (labor and material).**	13,000
• Epoxy-coat lime neutralization reactor tank.*	2,000
• Rubber-line all exposed carbon steel parts of one existing 6 ft x 6 ft Ametek rotary vacuum filter (job done at vendor shop).***	50,000
• Rubber-line all pumps exposed to pH 2.5 environment. Replace all piping, valves, and fittings with appropriate acid-resistant material.*	30,000
Instrumentation Changes Required:	
• pH control on first neutralization stage required to be more sensitive and reliable than currently available at Plant No. 2. Estimate for pH equipment replacement.*	5,000
TOTAL INVESTMENT COST	$ 300,000

* In-house estimate.
** Estimate provided by Tank Coatings, Inc., Pittsburgh, Pa.
*** Estimate provided by Rubber Covered Products, Smithfield, R.I.

Operating Cost*	Cost, $/yr
Precipitation/Neutralization System:	
• No significant increase in precipitation/ neutralization system operating cost expected over present operating cost of wastewater neutralization system. Lime consumption should actually decrease because of closer pH control in neutralization operation.	-
• Drying of 6.1 TPD precipitated calcium fluoride (dry 70% solids stream to <1% moisture in indirect gas heated rotary dryer using natural gas firing). With gas cost @ 4.00/MM Btu and energy utilization efficiency of 50%, drying cost is $2.40/1,000 lb feed.	1,000
• Briquetting of dried calcium fluoride @ $1.00/1,000 lb feed to one-inch, roughly spherical briquettes (no binder required).	3,000
• Direct labor and supervision (0.6 persons @ $20/hr).	29,000
• Maintenance costs (labor and materials) for drying and briquetting equipment @ $0.50/1,000 lb feed.	4,000
TOTAL ANNUAL OPERATING COST	$ 46,000
Savings due to replacing purchased fluorspar, 1,000 TPY @ $100/ton	$ 100,000
Savings due to reduction in offsite landfill disposal volume ($228,000/yr x .30)	68,000
GROSS ANNUAL SAVINGS (Pretax)	$ 168,000/year
Net Annual Savings = $168,000 - $46,000 = $122,000/year	
Payback Period Required:	
300,000/$122,000	2.5 years

*Based on 330 days/yr operation, 8 hrs/day for drying/briquetting operation.

This is a shorter payback period than the usually acceptable "rule-of-thumb" length of time for favorable investment payback (3 years). Based on an economic life of 5 years (20 percent amortization per year), the internal rate of return is approximately 28 percent (Riggs 1982).

An alternative to the use of existing equipment for the recovery of calcium fluoride by the selective precipitation technique (suggested for consideration by Plant No. 1 engineering personnel) would be a completely separate precipitation recovery system following which the partially treated combined pickle liquor/rinse water stream and the treated Kolene waste would be processed through the existing wastewater treatment system. A preliminary economic analysis for this alternative is presented below.

Capital Costs	Cost $*
Capital Equipment Requirements:	
• Agitator-equipped lime addition tank (epoxy-coated c.s.)	10,000
• Clarifier/thickener (epoxy-coated c.s.)	160,000
• Horizontal vacuum belt filter (corrosion-resistant)	340,000
Sub-Total	$ 510,000
• Carry-forward	$ 510,000
• Interconnecting piping, valves, fittings, and associated pumps @ 10% of equipment	51,000
• Gas-fired rotary dryer, c.s.	100,000
• Fluorspar briquetting equipment	100,000
• pH control instrumentation	5,000
TOTAL INSTALLED COST	$ 766,000

* In-house estimate supported by vendor quotes on specifically listed equipment.

Operating Cost*	Cost, $/yr
• Precipitation system - no increase in operating cost expected over present Plant No. 2 neutralization operation (assuming that the new calcium fluoride precipitation facilities can be located near the present wastewater treatment operation at Plant No. 1)**	-
• Other operating and maintenance costs (same as in previous operating cost calculation)	46,000
TOTAL ANNUAL OPERATING COST	$ 46,000
Annual pre-tax gross savings available (same as for earlier estimate)	$ 168,000/year

Net annual savings = $168,000 - $46,000
= $122,000/year

Payback period required:

766,000/122,000 — 6.3 years

This is a significantly longer payback period than the usually acceptable "rule-of-thumb" length of time for favorable investment payback (3 years).

In addition to the unfavorable economics of this alternative to the proposed waste minimization option, the audit team has serious concern about the availability of suitable space at Plant No. 1 for installation of the required equipment.

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* Based on 330 days/yr operation, 24-hr/day precipitation plant, 8 hrs/day calcium fluoride drying and briquetting plant.

** Estimated floor area required (assuming vertical arrangement possible with lime neutralization tank on top level, clarifier/thickener on middle level, and belt filter on ground level) is 1,600 sq. ft.

Summary and Discussion

A waste minimization option (recovery and recycle of calcium fluoride to the EAF steelmaking process for use as metallurgical flux and involving the use of existing equipment in Plant No. 1 pickling waste neutralization facility) has been developed and subjected to a preliminary engineering feasibility study by the audit team. Based on this study, the proposed recovery option appears technically and economically feasible.

A summary of the preliminary economics of this recycling option indicates the following:

• Total capital cost	$300,000
• Annual operating cost	$ 46,000/yr
• Savings due to replacement of purchased fluorspar	$100,000/yr
• Savings due to lower cost of offsite waste disposal	$ 68,000/yr
• Total potential savings	$168,000/yr
• Estimated payback period	2.5 years
• Estimated internal rate of return (based on an economic life of 5 years)	28 percent

The calcium fluoride recovery option and the related economic analysis were discussed with appropriate engineering personnel at Plant No. 1. Plant management is interested in the option although they have serious concern about the use of existing neutralization process equipment for calcium fluoride recovery. This concern is related to the possible loss of process equipment redundancy (specifically the clarifier and vacuum filter) through the implementation of the calcium fluoride recovery proposal. However, the audit team believes that this concern is unfounded. Since one clarifier/vacuum filter system would be able to handle the present wastewater flow if one of the other sets of these units were to go down for repairs, there would always be redundancy available in this system; i.e., the clarifier/filter system operating in the pH 2.5 mode could immediately switch to pH 8 operation (full neutralization without calcium fluoride recovery), if the other clarifier or filter units were down. As a further backup in this event, a suitable quantity of commercial fluorspar would always be kept on hand at the EAF

steel production facility in case the recycled material was not available. It is assumed that the revamp of the process units and related equipment discussed above would be accomplished during a Plant No. 1 turnaround, i.e., over a two-week period.

WMA AT PLANT NO. 2

Facility Description

This facility consists of cold-rolling equipment to convert raw stainless steel and electrical steel slabs into strip, annealing ovens, and a series of six pickling lines which acid pickle stainless and electrical steel strip produced in the cold-rolling equipment, as well as stainless and electrical hot-rolled steel strip produced in the EAF raw steel manufacturing facility (Plant No. 3). The six pickling lines in Plant No. 2 use HF, HNO_3, H_2SO_4, and mixtures thereof and have a total nameplate capacity of 1,833 tons per day of processed steel strip.

Process Description

Pickling line operations in Plant No. 2 can be summarized as follows:

- Line 2 consists of a shot blast descaling operation followed by a five-stage countercurrent pickling operation. In the first three stages, 5 to 18 percent sulfuric acid is used, and mixtures of 18 percent sulfuric and 3.5 percent hydrofluoric acids are used in the last two stages. Spray rinses are used at various stages in the pickling line, followed by a cold rinse and a hot rinse. Only silicon steels are handled on Line 2.

- Line 3 also handles silicon steels and consists of a five-stage countercurrent pickling operation, followed by a cold rinse and a hot rinse. Sulfuric acid of from 2 to 20 percent strength is used in the first four stages, and a mixture of 15 percent H_2SO_4 and 2 percent HF is used in the final stage.

- Line 4 consists of a two-stage stainless steel pickling operation. Sulfuric acid at 15 percent strength is used in the first stage, and a 10.5 percent HNO_3, 2.3 percent HF mixture is used in the second stage. A cold rinse follows each stage of acid pickling.

- Line 7 consists of a single-stage pickling line for stainless steels, followed by a cold rinse. The pickling solution consists of a mixture of 16.9 percent H_2SO_4 and 1.5 percent HF.

- Line 12 consists of a three-stage countercurrent pickling line for silicon steels, followed by cold and hot rinses. All three stages use sulfuric acid with concentrations ranging from 3.5 to 15.5 percent. Initial descaling is accomplished by a shot blast treatment.

- Line 23 consists of a shot blast descaling treatment followed by a two-stage pickling operation for stainless steels. In the first stage, 16 percent sulfuric acid is used, and a 9.1 percent HNO_3/0.14 percent HF mixture is used for the second stage. A rinse follows each stage of pickling.

Emissions from all of the pickle lines are controlled by use of fume scrubbers. Following pickling, the treated strip is wound into coils and shipped. Figure 7 presents a simplified, overall process diagram for the entire operation.

Waste Stream Description

The six pickle lines generate the following spent pickling acids: dilute spent sulfuric acid, dilute spent mixed sulfuric-hydrofluoric acid mixtures, and dilute spent mixed nitric-hydrofluoric acid mixtures. Table 8, based on typical operational data and 20 turns (shifts) per week operation per pickling line, shows the amounts and compositions of waste pickle liquor and rinse water generated by each of the Plant No. 2 pickling lines. About 313,000 gallons of spent sulfuric acid, 144,000 gallons of spent sulfuric/hydrofluoric acid mixture, and 12,000 gallons of spent hydrofluoric/nitric acid mixture are generated per week. Also, about 9.7 million gallons/week of rinse water are generated with much lower concentrations of the spent acids and dissolved metals.

Current Waste Treatment Practice

The six pickling lines at Plant No. 2 have been added piecemeal over a number of years beginning in 1927 (the most recent line was installed in 1961), and although laid out roughly parallel to each other, they do not discharge pickling and rinse water wastes separately into a down stream manifold. The waste discharges are fed into various trunk lines under the pickling room floor in an irregular pattern terminating in a common discharge flume outside the building. The final combined waste discharge (K062) contains spent pickle liquors (mixed nitric, sulfuric, and hydrofluoric acids) together with dissolved salts of iron, chromium, nickel, and cadmium. The average composition of the combined waste stream (in terms of critical metal and non-metal parameters) is as follows:

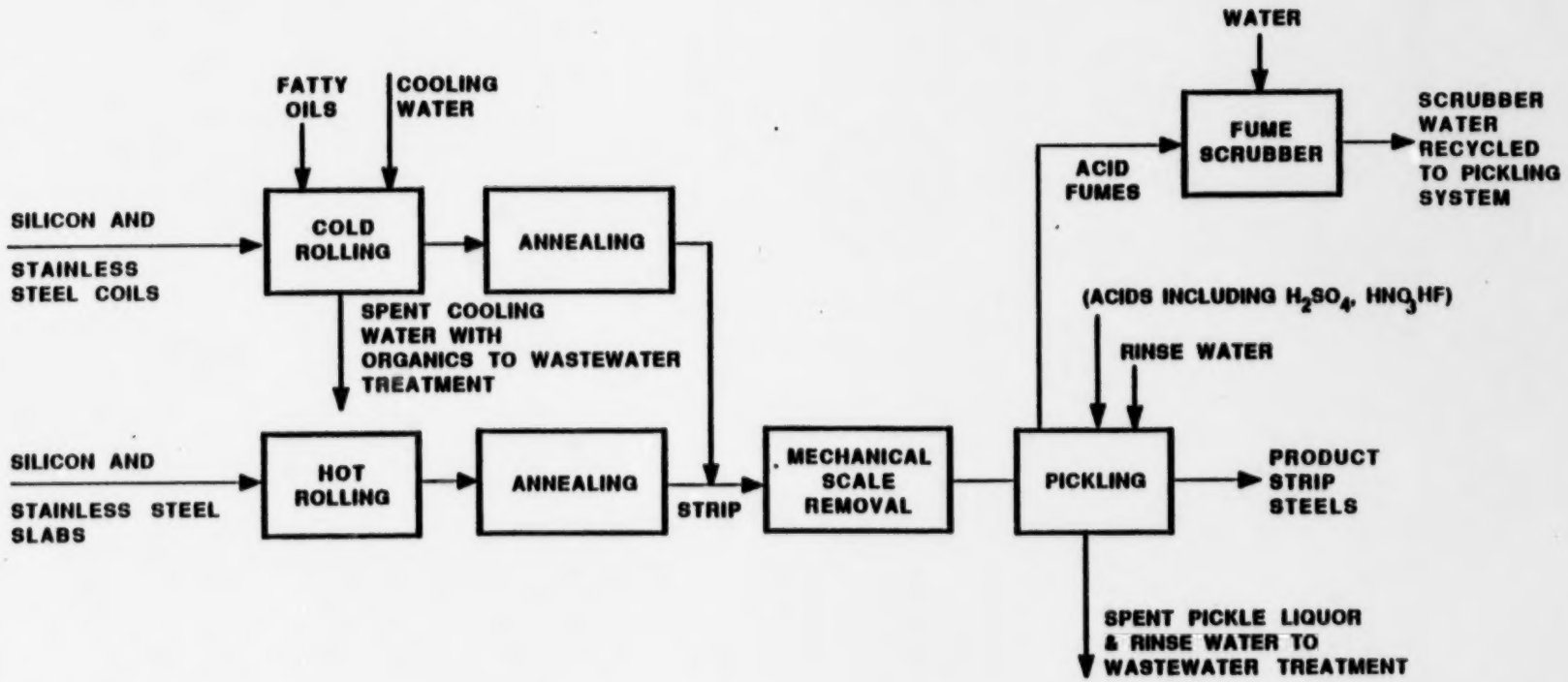

Figure 7. Simplified Schematic Of Existing Pickling Facilities At Plant No. 2.

Table 8. ACID PICKLING WASTES GENERATED AT PLANT NO. 2

Pickling line #	Amount waste sulfuric acid generated (gal/week)	Composition (range)	Amount spent HF/H_2SO_4 generated (gal/week)	Composition (range)	Amount HF/HNO_3 generated (gal/week)	Composition (range)	Amount of rinse water & quench water generated (gal/week)
2	None		69,000	0-5.5% H_2SO_4 0-3.5% HF 6.1% metals	None	-	1,930,000
3	None		36,000	0-1.9% H_2SO_4 0-1.8% HF 5.9% metals	None	-	2,310,000
4	128,000	0-15.5% H_2SO_4 7.1% metals*	36,000	-	6,000	0-10.5% HNO_3 0-2.3% HF 4.9% metals	2,210,000
7	None	-	3,000	0-16.9% H_2SO_4 0-1.5% HF 3.7% metals	None	-	1,000,000
12	180,000	0-3.5% H_2SO_4 7.3% metals	None	-	None	-	1,200,000
23	5,000	0-16.3% H_2SO_4 5.5% metals	None	-	6,000	0-9.1% HNO_3 0-0.14% HF 7.6% metals	1,060,000
Totals	313,000		144,000		12,000		9,710,000

*Metals encountered in pickle liquor wastes (depending on the type of steels being pickled), include Fe, Cr, Ni. The predominant metal is Fe.

Parameter	Average concentration, mg/l
Cr	49
Ni	28.5
Cd	<0.02
Fe	500
Fluoride	39
pH	~2

This stream also contains emulsified and free fatty oil and grease from cold rolling operations at this facility. The combined wastewater discharge from Plant No. 2 is sent to a central treatment facility on site where it is treated with lime to effect precipitation of metals as the corresponding hydroxides and removal of fluoride as calcium fluoride. The treated wastewater slurry is then pumped to a series of onsite large lagoons where the suspended solids are removed by sedimentation and the treated wastewater is then discharged to the outfall. The precipitated solids meet EP-toxicity test levels for hazardous metals and the treated wastewater is discharged to a local creek under an NPDES permit. Figure 8 is a simplified schematic of the Plant No. 2 combined wastewater treatment system.

Postulated Waste Minimization Options

During the formal audit phase of this study at the Plant No. 2 acid pickling facility, the use of source reduction and/or resource recovery options was studied by the audit team. The current neutralization treatment of the combined pickling and cold-rolling aqueous waste stream (listed waste K062) generates a mixed metal hydroxide-gypsum-calcium fluoride sludge for which there is no reuse potential. The key to waste minimization at this plant is suitable segregation of selected spent acid wastes before these wastes are combined at the outlet flume -- an option that plant personnel indicated would be highly disruptive to plant operations and costly as well. Assuming that pickling waste stream segregation is feasible, however, the following waste minimization option would be proposed by the audit team:

- As a recycling option, segregate an appropriate amount of the waste sulfuric acid pickle liquor (13.5 million gallons per year are potentially available from three pickling lines; see Table 1).* Two uses for this material were identified by the audit team:

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* Based on 300 days per year (43 weeks/yr) operation of the Plant No. 2 acid pickling lines.

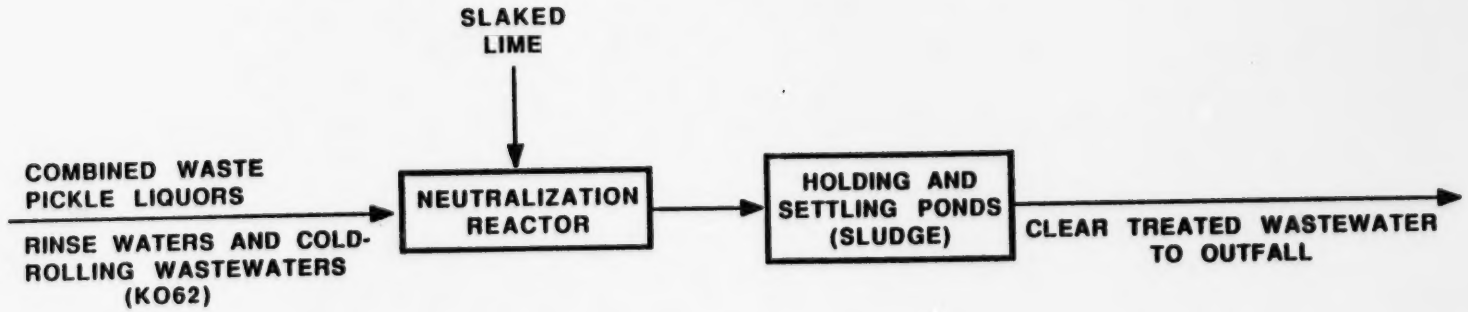

Figure 8. Simplified Schematic of Plant No. 2 Pickling Process Wastewater Treatment.

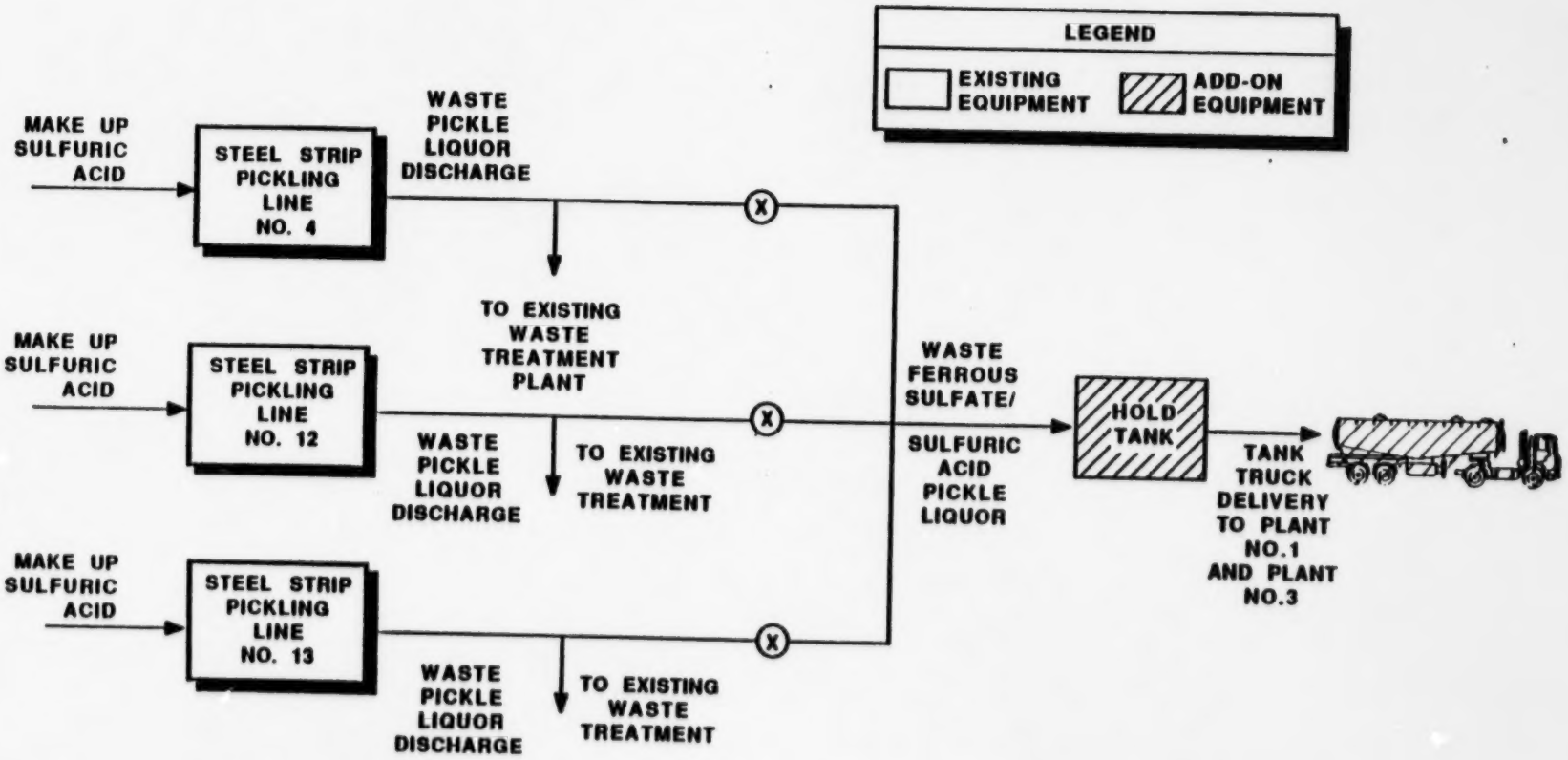
LEGEND
EXISTING EQUIPMENT
ADD-ON EQUIPMENT
MAKE UP SULFURIC ACID
STEEL STRIP PICKLING LINE NO. 4
WASTE PICKLE LIQUOR DISCHARGE
TO EXISTING WASTE TREATMENT PLANT
MAKE UP SULFURIC ACID
STEEL STRIP PICKLING LINE NO. 12
WASTE PICKLE LIQUOR DISCHARGE
TO EXISTING WASTE TREATMENT
MAKE UP SULFURIC ACID
STEEL STRIP PICKLING LINE NO. 13
WASTE PICKLE LIQUOR DISCHARGE
TO EXISTING WASTE TREATMENT
WASTE FERROUS SULFATE/ SULFURIC ACID PICKLE LIQUOR
HOLD TANK
TANK TRUCK DELIVERY TO PLANT NO.1 AND PLANT NO.3

Figure 9. Proposed Recovery System For Waste Ferrous Sulfate/Sulfuric Acid Pickle Liquor Recovery From Plant No. 2 Acid Pickling Waste Discharge.

- Reduction of hexavalent chromium in a bleed stream of venturi scrubber waste resulting from scrubbing of EAF dust in Plant No. 3 (see Section 5).

- Reduction of hexavalent chromium in the Kolene waste (see Section on "Current Waste Treatment Practices").

  Both of these uses presently employ purchased solid ferrous sulfate heptahydrate. Recycled sulfuric acid pickle liquor (containing 5 to 10 percent dissolved ferrous sulfate) is known to be usable for this purpose.

The technical and economic feasibility of this recycling option was evaluated by the audit team as discussed in the following section. No source reduction options were identified by the audit team.

Feasibility Analysis of Selected Waste Minimization Options

Under this option, it is proposed to recycle waste sulfuric acid pickle liquor from Plant No. 2 pickling lines #4, #12, and #23. Based on an engineering study by Plant No. 2 personnel, a decision would be made on the feasibility of which of these pickling line discharges can be tapped for an appropriate volume of this material. This waste pickle liquor would be collected in a suitable holding tank system and subsequently used for hexavalent chromium reduction in EAF steel melt shop and Plant No. 1 operations in place of presently purchased ferrous sulfate heptahydrate powder.

The proposed process modifications needed to recover the waste ferrous sulfate pickle liquor are shown in simplified schematic form in Figure 9 and consist of the following:

- Segregate approximately 3.9 million gallons per year of waste sulfuric acid pickle liquor from pickling line 4, 12, or 13 waste discharges. This material contains 5 to 10 percent ferrous sulfate and is to be used in place of 370 tons per year (TPY) of purchased ferrous sulfate heptahydrate. Of the latter amount, 240 TPY is used for hexavalent chromium reduction in the raw Kolene waste treated at Plant No. 1 and 130 TPY is used for hexavalent chromium reduction in Plant No. 3 (the EAF steelmaking production area) for treatment of a blowdown venturi scrubber stream (see Section 3.).

- The ferrous sulfate/sulfuric acid pickle liquor diverted from the Plant No. 2 waste disposal and treatment system is piped to a 20,000-gallon acid-resist tank (FRP construction), located in a presently vacant bunker area behind the Plant No. 2 neutralization system. This area has truck access. Delivery from a suitable waste acid loading system in this area to the use locations in Plant No. 1 and Plant No. 3 would be made by a company-owned 5,000-gallon acid-resistant tank truck making 3 trips per day to deliver the required quantities of waste pickle liquor. A 10,000-gallon FRP tank would hold the supply of waste pickle liquor needed for Plant No. 1 operation, and a 5,000-gallon FRP tank would hold the Plant No. 3 requirements at the respective locations.

The economic feasibility of this option (including estimated capital and operating costs) is presented below.

Capital Cost	Cost $
• Tankage, piping, and pumps (installed)*	100,000
• Tank Truck**	105,000
• Cost of obtaining hazardous waste permit (plant estimate)	50,000
TOTAL INVESTMENT	$ 255,000

Operating Cost	Cost $/yr)
Labor (including operation of waste sulfuric acid pickle liquor storage facility at main plant and delivery of pickle liquor to use areas in Plants Nos. 1 and 3)*	10,000
Truck operation and maintenance**	10,000
TOTAL OPERATING COST	$ 20,000

Annual savings due to replacing purchased ferrous sulfate heptahydrate with waste ferrous sulfate pickle liquor, 370 TPY @ $120/ton***	$ 44,400
Annual savings due to lower lime usage for neutralization at Plant No. 2 (~150 TPY @ $50/ton)	7,500
Gross Pre-Tax Annual Savings	$ 52,000 (rounded)

Net annual savings = 52,000 - 20,000
= 32,000/year

Payback period required:

255,000/32,000 — 8.0 years

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* Audit team estimates. Includes one 20,000-gallon FRP storage tank, piping, pumps, and truck loading station at Plant No. 2 pickling facility, one 5,000-gallon FRP storage tank, pump, and piping at Plant No. 3 melt shop area, and one 10,000-gallon FRP storage tank, pump, and piping in the Plant No. 2 neutralization plant area.

** Matlack Trucking, N.J., estimate for 5,000-gallon tractor-trailer with trailer meeting DOT Spec. MC312 for 5 percent sulfuric acid solution.

*** Combined usage at Plant No. 1 and Plant No. 3 for chromate reduction. Cost of chemical is current plant cost.

The payback period of eight years is almost three times the usually acceptable period of three years, making the proposed project distinctly unattractive from an economic standpoint.

SUMMARY AND DISCUSSION

A waste minimization option (segregation and reuse of approximately 29 percent of the waste sulfuric acid/ferrous sulfate pickle liquor generated in Plant No. 2 for in-house treatment of hexavalent chromium replacing purchased ferrous sulfate heptahydrate) has been developed and subjected to a preliminary engineering and economic feasibility study. Based on the study, this recovery option does not appear economically feasible.

This option was discussed with appropriate engineering personnel at Plant No. 2. In addition to the obvious economic disadvantage of this option, plant personnel were concerned with the cost and disruption of decoupling the internal discharge points of this waste (in the pickling process building) needed to segregate the appropriate amount of this waste for recycle. No information was available from the plant to permit estimation of the cost of decoupling this waste quantity from the remaining waste streams discharged from the facility. However, since the use of this option does result in some waste minimization as well as a small but measurable extension in the life of the present waste lagoon disposal system (approximately 10 percent less calcium sulfate and metals-containing solids would be deposited in the lagoons), the audit team believes that the option should continue to be reviewed at Plant No. 2.

SECTION 5

HEAVY METAL WASTES - WMA CASE STUDIES

One facility was selected as a host site for a WMA at an industrial generator of heavy metals waste. The plant involved is located at an EAF steelmaking complex in the East. The facility, the EAF steelmaking melt shop and related waste treatment areas, is designated in this report as Plant No. 3.

FACILITY DESCRIPTION

Plant No. 3 in the EAF steelmaking complex consists of three EAFs producing raw stainless and electrical steels. The raw steel is cast into slabs using two continuous casters. Some of the raw steel is further refined using an argon-oxygen decarburizing (AOD) furnace before being cast into slabs. The slabs are converted into strip using furnaces and hot mills. Plant capacity is between 650,000 and 700,000 TPY, the bulk of which are 300 and 400 grades of stainless steel, with the balance being various grades of electrical (silicon) steel.

PROCESS DESCRIPTION

EAF process equipment consists of three top-charge furnaces. Each EAF has a rated steelmaking capacity of 165 tons per heat (i.e., 165 tons per batch of steel produced).* Each furnace unit is equipped with (1) a roof lift and swing arrangement that permits the roof to swing aside when cold scrap is charged into the furnace; (2) a rocker and rail tilting type arrangement that permits the furnace to tilt forward for tapping and backward for slagging; (3) a system for additions through the furnace roof; and (4) evacuation systems for the removal of dust generated during the steelmaking cycle.

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*The charge to each furnace includes various grades of steel scrap, ferro alloys, and metallurgical fluxes (including fluorspar).

A number of electrodes are supported by electrode arms and clamps, and project from overhead down through the furnace roof. The electrodes are automatically controlled by an electro-mechanical positioning mechanism. An electric arc surging between the electrodes and scrap produces heat that melts the charge in the presence of oxygen and refines the steel. The molten steel is tapped (at a temperature of about 3000°F) into a ladle and continuously cast into slabs, and later is converted into strip.

The EAFs generate particulate emissions during (1) charging of scrap, (2) tapping of furnaces, (3) pneumatic injections of additives, (4) oxygen blowing, and (5) meltdown/refining periods. The EAF particulate (listed hazardous waste K061) is collected in a venturi scrubber tied to the EAF exhaust. Each EAF is equipped with a separate venturi scrubbing system. An AOD furnace used to further refine some of the stainless steel grades discharges EAF dust, which is collected in a baghouse along with fugitive emissions from the three EAFs. This EAF/AOD dust is also discharged from the plant as K061 waste.

Figure 10 is a simplified schematic of the EAF steelmaking process and the EAF dust collecting technologies.

WASTE STREAM DESCRIPTION

Plant No. 3 currently generates about 8,000 TPY of EAF dust from steelmaking operations. Of this amount, 7,000 TPY is collected by the venturi scrubbing system and 1,000 TPY is collected by the baghouse system. Table 9 is the most recent total analysis available (dry basis) of the EAF venturi scrubber sludge; the data shown were obtained in 1983. Table 10 provides two sets of data developed in 1984 on heavy metals concentrations in this waste. Table 11 presents a comparison of hazardous heavy metals in the baghouse and venturi scrubber system discharges, as well as EP-toxicity test data on these respective discharges (all 1983 data).

WASTE TREATMENT PRACTICE

The present treatment practice for EAF dust collected by the venturi scrubbing system consists of a water clarification system for the venturi scrubber slurry (the latter contains about 10,000 ppm solids as produced in the venturi scrubbers), and a system for treatment of a blowdown stream of recycle water from the venturi scrubber slurry clarification step (about 10 percent of the venturi scrubber flow), for hexavalent chromium reduction. The clarifier underflow sludge is filtered in a rotary vacuum filter. The filter cake (about 70 percent solids and totaling 10,000 TPY) is then combined with the baghouse dust collected

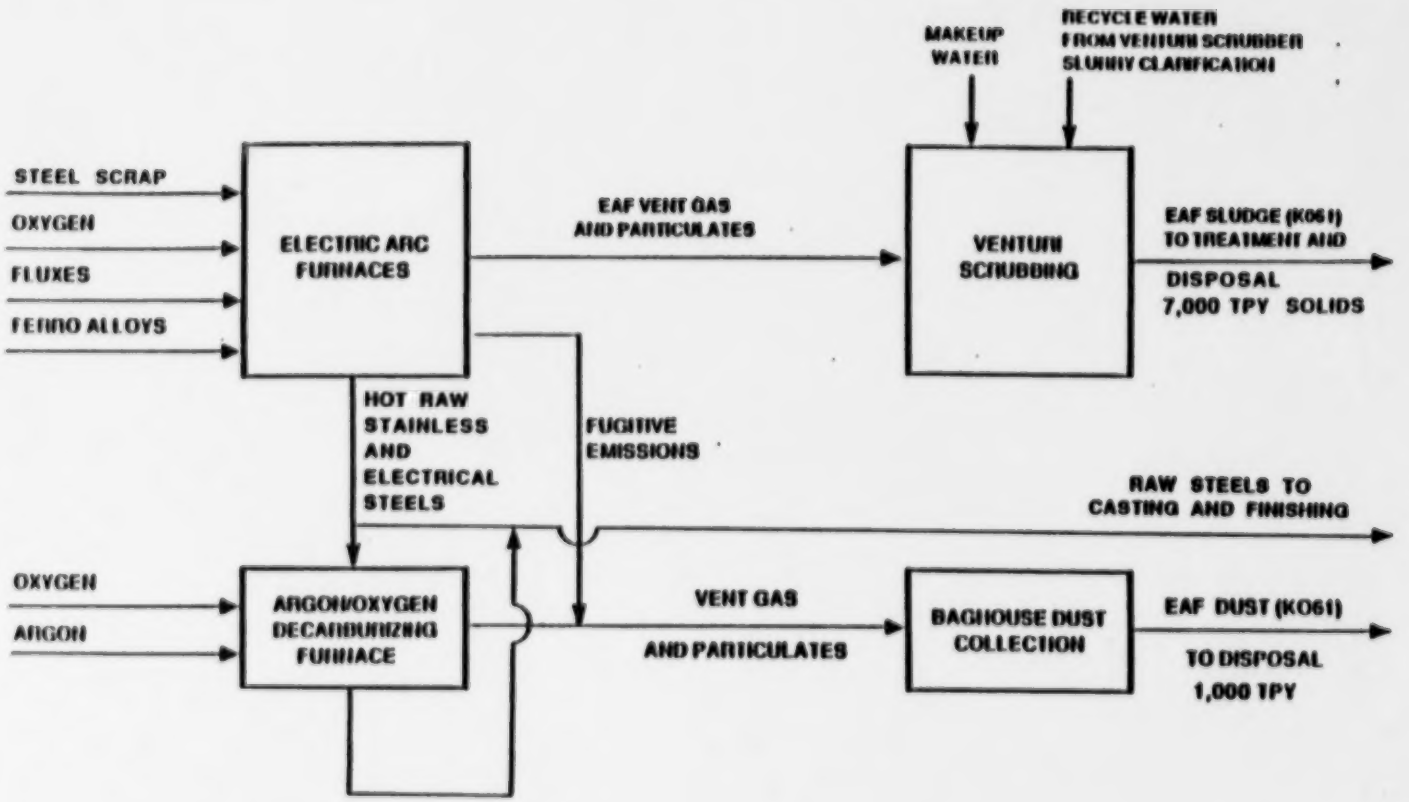

Figure 10. Simplified Schematic Of K061 Waste Generation At Plant No. 3 Melt Shop.

Table 9. COMPOSITION OF EAF VENTURI SCRUBBER SLUDGE (K061) ON DRY BASIS*

Parameter	Amount present (weight percent)
Iron	39.9
Manganese	3.4
Silica (SiO_2)	4.9
Aluminum	0.3
Calcium	3.1
Chromium (total)	1.7
Copper	0.25
Nickel	0.36
Lead	3.1
Zinc	10.5
Magnesium	2.3
Cadmium	0.041
Barium	0.011

*1983 data.

Table 10. HEAVY METALS CONTENT OF EAF DUST (K061)*

Parameter	Data set #1	Data set #2
Arsenic	68	56
Barium	<50	<50
Cadmium	50	130
Chromium (Total)	9,800	17,000
Lead	3,100	670
Mercury	1.0	0.8
Nickel	7,500	2,000
Selenium	7	23
Silver	40	30
Copper	2,200	1,000
Molybdenum	360	110
Zinc	300,000	110,000

*In units of ug/g. 1984 data.

Table 11. COMPARATIVE K061 WASTE AND EP-TOXICITY TEST HAZARDOUS HEAVY METALS ANALYSES - BAGHOUSE DUST AND VENTURI SCRUBBER SLUDGE*

Parameter	Waste data		EP-Toxicity test data	
	Baghouse dust (%)	Venturi scrubber sludge (%)	Baghouse dust (mg/l)	Venturi scrubber sludge (mg/l)
Total chromium	2.7	0.8	56.2	0.28
Lead	0.56	1.6	0.19	172
Cadmium	0.0045	0.05	0.37	12.1

*1983 data.

from the decarburizing operation and melt shop fugitive emissions, and the total waste stream (11,000 TPY) classified as K061 is sent to offsite licensed hazardous waste landfills. The cost of disposing of this waste is about $1.0 million per year.

With respect to handling the blowdown stream of venturi scrubber recycle water, this stream is treated in a reaction tank with an excess of ferrous sulfate heptahydrate for a period of about 80 minutes. This treatment results in the reduction of hexavalent chromium to the trivalent form. Following treatment, the resulting slurry is sent to an onsite storage pond where the sludge is allowed to settle and the supernatant discharged to a local creek under an NPDES permit. The settled solids (nonhazardous based on EP-toxicity testing) are intermittently sent off site to a nonhazardous waste landfill.

Figures 11 and 12 are simplified schematics of the venturi scrubber slurry treatment system and venturi recycle water blowdown treatment system, respectively.

POSTULATED WASTE MINIMIZATION OPTIONS

During the formal audit phase of this study at Plant No. 3 (EAF steelmaking melt shop), process and waste treatment operations were intensively studied by the audit team. The use of various potential source reduction and recycling options for K061 waste was reviewed with plant personnel, as discussed below.

With respect to source reduction to minimize K061 waste generation, the following information was developed:

- With the primary steel products of the Plant No. 3 facility being 300 and 400 stainless grades, there will always be significant levels of the hazardous metals chromium and nickel (due to the alloying requirements of stainless steels), as well as lead in the EAF dust. Contributions to these metals in the EAF dust come from the scrap feed as well as from the alloying additives. These EAF dust constituents, therefore, will always be in excess of the presently allowable RCRA levels in leachate generated in the TCLP procedure. Source reduction is thus not an available option to the plant.

With respect to the recycle of K061 waste at Plant No. 3, the company has made and is making a number of attempts to recycle the EAF dust to the steelmaking process. These may be summarized as follows:

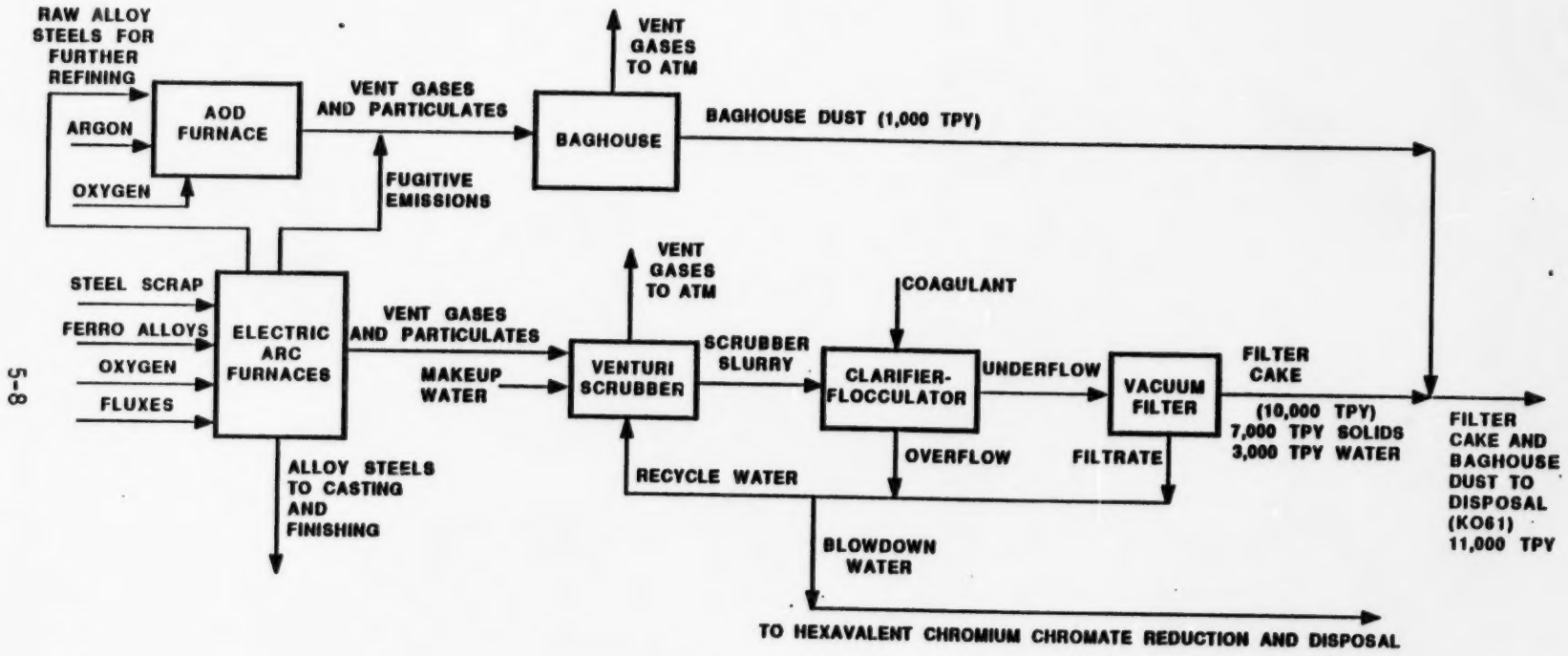

Figure 11. Simplified Schematic Of EAF Dust Treatment At Plant No. 3.

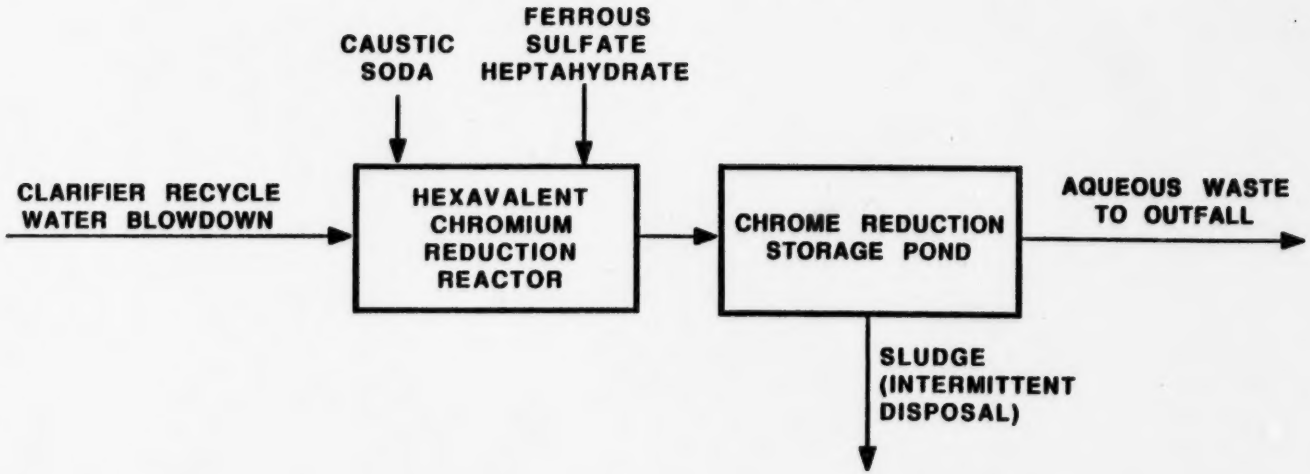

Figure 12. Simplified Schematic Of Hexavalent Chromium Reduction Treatment Of Venturi Scrubber Blowdown At Plant No. 3.

- Two trials of EAF baghouse dust recycle to the furnaces failed because of physical handling problems. The dust was essentially all blown out of the furnace before it could be remelted.

- A trial of the recycle of briquetted EAF baghouse dust resulted in about 40 percent of the briquetted material being blown out of the furnace.

- Current treatment of the EAF venturi scrubber slurry results in a 30 percent moisture filter cake waste discharge (attempts to dewater this material further have failed). The moisture content must be reduced to a maximum of 5 percent before the waste material can be recycled to the furnaces. This is an expensive procedure. However, a trial is planned by Plant No. 3 to dry and briquet this material and then attempt to recycle the treated material to the furnaces.

- Plant personnel also indicated that because of the volumes of dust generated and the sensitivity of the steel product quality to tramp elements in the recycled dust, it is unlikely that a large percentage of this waste could ever be recycled to the process.

With respect to reclamation of metal values in K061 waste generated by Plant No. 3, the following information was developed by the audit team, from both discussions with Plant No. 3 personnel and outside literature research:

- The principal ingredient of value (zinc) is only present to the extent of 8 to 10 percent in the Plant No. 3 EAF dust. In order for EAF dust to be economically attractive to commercial reclaimers, it should have at least 20 percent zinc, preferably nearer 50 percent. Additionally, internal recycling of the EAF dust, which would tend to enrich the zinc content of the residual material, is presently not available to Plant No. 3 for reasons given above.

- A potentially commercially viable zinc and lead reclaiming process now in the demonstration plant stage is the St. Joe Flame Reactor process, a description of which has recently appeared in the literature (Pusateri 1986). The following information is available on this process:

  - In brief, the St. Joe Flame Reactor process is claimed to be a unique, two-stage, carbon-fueled flash smelting system developed to treat metal oxide-containing feeds. The reactor separates carbon-fuel gasification in oxygen-enriched air from metal oxide

reduction/melting reactions at high temperatures (2700° to 3200°F). Recirculation-stabilized gas flow re-entrains unreacted particles and is claimed to result in a high intensity, compact, low-cost reactor unit. Reactor residence time is typically 0.1 to 0.5 second. Pilot and demonstration plant testing has included coal gasification and smelting of zinc calcine and several zinc- and lead-bearing residues and secondaries, as well as a delisted EAF dust. Current testing under an EPA RD&D permit is employing various K061 wastes.

- The process is claimed to be commercially viable for feed rates of EAF dust up to 2.5 TPH to recover crude ZnO and PbO and produce a nonhazardous slag. Nominal concentration of ZnO in the reactor feed is at least 20 percent by weight. Recoveries of zinc and lead as crude oxide are typically 92 to 95 percent and 94 to 98 percent, respectively.

- Commercialization of this process for treatment of EAF dust at steel plant sites is planned for 1987-1988. Eventually, St. Joe Minerals hopes to operate contract onsite treatment facilities at EAF steel plants. Toll charges would be based on values of recovered materials (lead and zinc oxides); the more recoverable the material, the less the toll charges.

- The St. Joe approach may be a way for Plant No. 3 to recover zinc and lead values from its K061 waste (although the bulk of this material would have to be pre-dried prior to being processed and the zinc content of the feed would be significantly lower than 20 percent) when the St. Joe process is fully available on reasonable terms and conditions for use on a tolling basis.*

- The St. Joe process has been considered a recycle option (as a Plant No. 3 company-owned process) in the present study even though the process cannot be considered commercially proven at this stage in its development.

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* It should be noted that the slag produced by this process would have to be delisted to make it acceptable for disposal in nonhazardous waste landfill.

No commercially viable source reduction and/or recycle or resource recovery options appear to be available at this time to reduce the quantity of K061 waste generated at Plant No. 3. The alternative treatment step proposed by the audit team was discussed with plant personnel, and they were in agreement that the approach appears to be the only one available at the present time. It should be noted that the proposed option is not true waste minimization. The option may be summarized as follows:

- Convert the K061 waste into a nonhazardous material using a chemical stabilization/solidification technique (using lime kiln and/or cement kiln dust and water blended with the EAF dust and sludge to generate pozzolonic reactions and create an essentially insoluble concrete-like matrix), apply to have the waste delisted by EPA, and dispose of the delisted material in an onsite dedicated landfill. Figure 13 is a simplified schematic of the proposed treatment option.

FEASIBILITY ANALYSIS OF SELECTED WASTE MINIMIZATION OPTIONS

In this section, the audit team presents the results of its engineering and economic evaluations of a treatment option for the detoxification of K061 waste at Plant No. 3. Additionally, projected cost information available in the public literature is presented on the St. Joe Flame Reactor Process, which, while not now a commercially available resource recovery option, may be available in several years based on discussions with the process developer.

Proposed Alternative K061 Waste Treatment Process

The proposed treatment option would involve adding lime kiln or cement kiln dust and an appropriate amount of water (although no water may be needed since the bulk of the K061 waste consists of a filter cake containing 30 percent water) to the blended K061 waste (90 percent filter cake, 10 percent baghouse dust), using suitable mixing equipment, and then placing the mix in an onsite dedicated landfill. It may also be necessary to add small amounts of soluble silicates to immobilize chromium as an inert, non-leachable chromium silicate, since chromium is known to leach out of lime or cement-stabilized K061 waste.*

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* Plant No. 3 personnel have noted this problem with chromium in their own laboratory tests of this approach to K061 waste treatment.

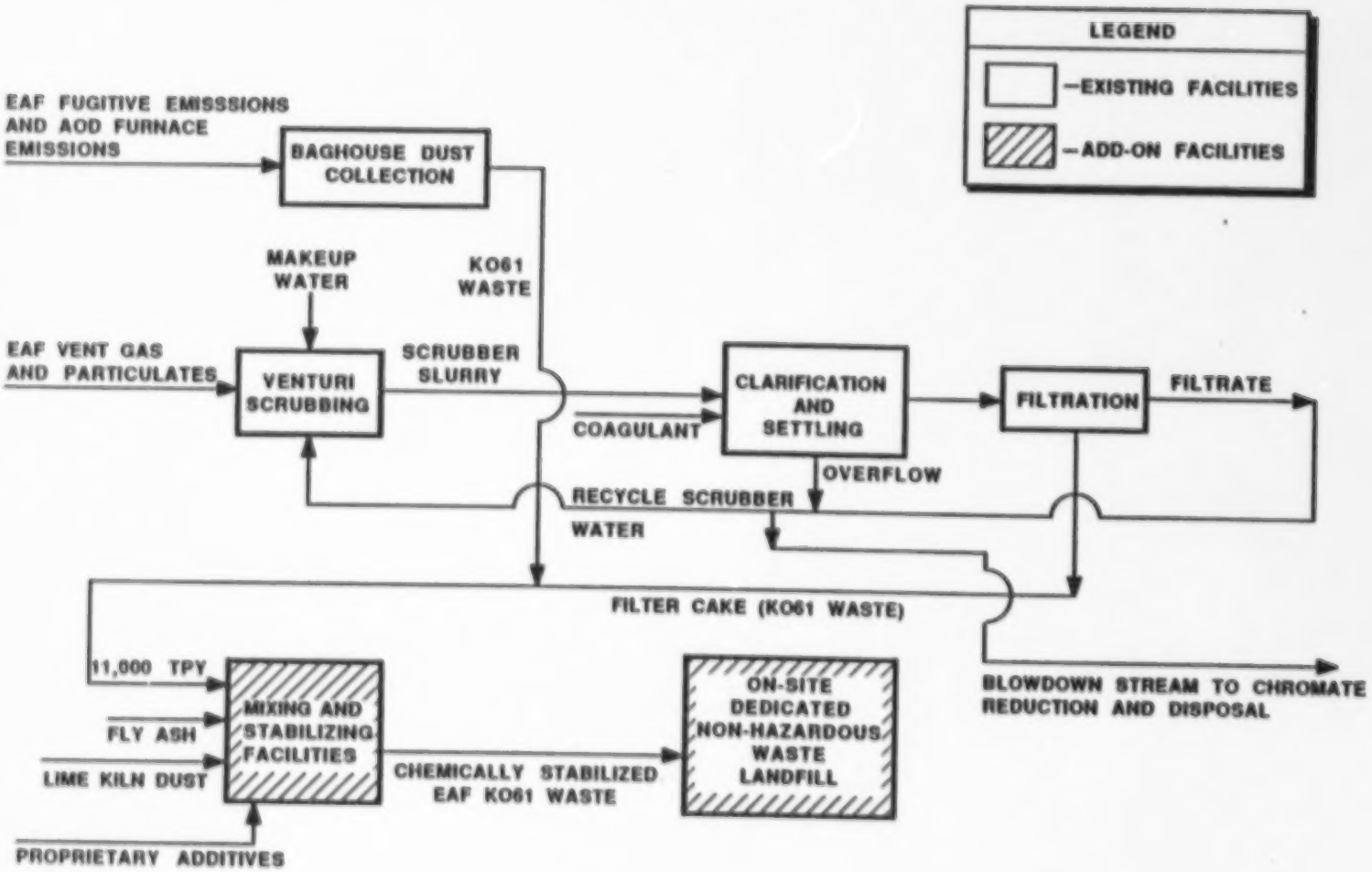

Figure 13. Simplified Schematic Of Proposed Modification Of KO61 Waste Treatment At Plant No. 3.

The treatment option proposed by the audit team is similar to a process being studied by the Bethlehem Steel EAF Steel plant at Steelton, Pennsylvania, which generates a K061 waste similar in hazardous heavy metals composition (except for chromium) to the waste currently produced at Plant No. 3. Bethlehem Steel has used this pozzolonic immobilization technique for treatment of K061 waste in bench scale tests, and the solids produced appear to pass the EPA delisting requirements for lead, cadmium, total chromium, and nickel. Bethlehem Steel has petitioned to have the immobilized/stabilized waste delisted. The petition, which includes a description of the company's proposed K061 waste stabilization process, is currently under review by EPA (Bethlehem Steel 1986), and preliminary indications are that the stabilized/solidified material produced by this method has an excellent chance of being accepted by EPA as a delisted waste (which would probably be disposed of in an existing onsite landfill) by the end of 1986 or early 1987. Table 12 presents the current allowable limits of hazardous heavy metal concentrations for TCLP* test leachate from a detoxified material described in any currently submitted K061 delisting petition, and Table 13 provides information on the Bethlehem Steel chemically-stabilized K061 waste.

The treatment option proposed by the audit team would be carried out as follows:

- The 11,000 TPY of K061 waste filter cake and dust would be blended on a concrete mixing pad, with lime kiln dust, any water required, and any special additives required (such as soluble silicates), using a front-end Rototiller-type self-propelled mixer. For the proposed stabilization process, a one to one weight ratio of lime kiln dust to K061 waste has been assumed. A front-end loader would be needed to bring the generated wastes to the mixing pad. This procedure is carried out to approach the desired physical and chemical properties in the final stabilized product.

- The mixed waste/lime kiln dust/water/additive material would be transported by dump truck to the dedicated onsite landfill where the material would be placed in suitable lifts using a front-end loader. A sheep-foot (or equal) compactor would be used to compact the material to the required degree of compression. Regulations in the State where Plant No. 3 is located require that this landfill use a synthetic liner (or equivalent clay liner) system. Figure 14 is a simplified schematic of such a landfill design.

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* Toxicity Characteristic Leaching Procedure.

Table 12. ALLOWABLE EP-TOXICITY TEST LIMITS FOR HAZARDOUS HEAVY METALS IN LEACHATE FROM DETOXIFIED K061 WASTE

Parameter	Allowable limit (mg/l)*
Total chromium	0.32
Lead	0.32
Cadmium	0.063
Nickel	0.35

*These levels (for total chromium, lead, and cadmium) represent 6.3 x drinking water standards and are set for K061 waste based on the EPA VHS model and a 5,000 - 10,000 TPY K061 waste generation rate. The level for nickel is derived from EPA health and toxicological studies, and the basis for this value is contained in the Federal Register notice of May 15, 1985 (50 CFR pp. 20239-20248).

Table 13. PHYSICAL DESCRIPTION OF CHEMICALLY CURED STABILIZED EAF DUST, BETHLEHEM STEEL CORPORATION, STEELTON PLANT*

Color:	Brownish-black
Odor:	None
Percent bound moisture:	<10%
Free liquids:	None
Layers:	None (Single-phased homogeneous solid)
Bulk density:	94 lb/ft^3 (1.27 tons/cubic yard)
Specific gravity:	2.40
Ignitability:	Negative
Reactivity:	Negative
Corrosivity:	Negative
Volatiles:	Negative

*Source: Bethlehem Steel 1986.

The economic viability of this treatment option, based on preliminary capital and operating cost estimates, is presented below:

Capital Costs

Annual disposal rate = 11,000 waste + 11,000 TPY lime kiln dust
= 22,000 TPY
22,000 TPY @ 90 lb/CF = 489,000 CF/yr
Compacted to 92% theoretical density
= 450,000 CF/yr
Assume that 10 years of onsite disposal are to be provided for a 10-foot high onsite landfill.
Onsite acreage required = 11.25 acres.

Capital Equipment and Facilities (waste stabilization)

Item	Cost,$
- Site preparation.	$10,000
- Concrete mixing pad 20 x 25 x 1 ft thick; reinforced 35000 psi RediMix concrete; side walls 30 in high; open ends.	8,500
- Shelter bldg. over pad area; 30 x 40 x 10 or 12 ft high; prefab steel corrugated roof and sides (could be reinforced fiberglass); double doors both ends; unheated; complete, erected.	25,000
- Electrical and water in shed.	3,000
Sub-Total	$46,500
Carry-forward	$46,500
- Storage bin for lime dust (approx. 5 days supply); 12 x 12 x 25 cone bottom; w/slide gate spout discharge and covered top with pneumatic fill attachment.	18,000
- Bob-Cat front-end loader; 3/4 cubic yard (CY) bucket dedicated to K061 service; totally enclosed operator's cab with fresh air intake particulate filter.	60,000

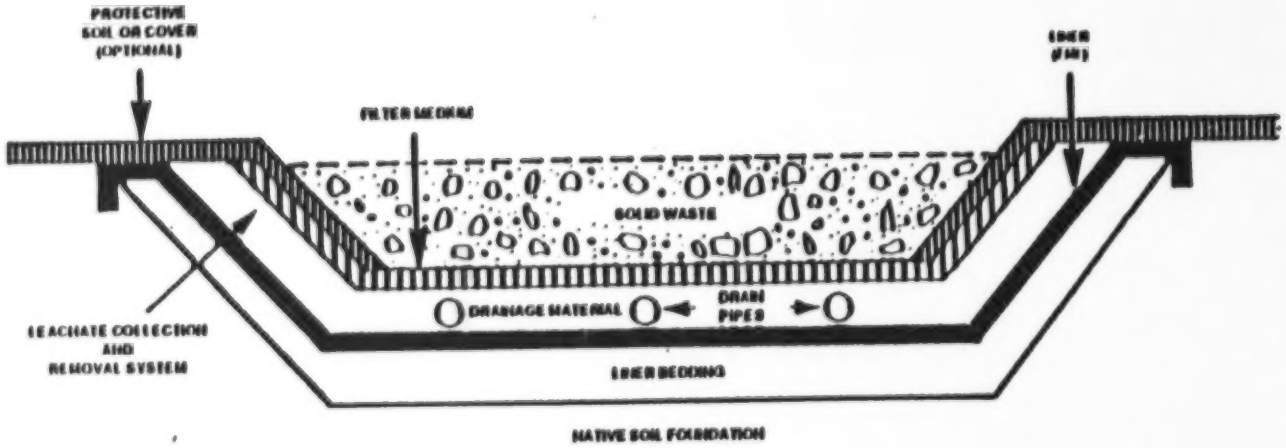

Figure 14. Schematic Of Flexible Membrane Single Liner System For An Onsite Landfill.

- Front-end Rototiller-type self-propelled mixer, 4 ft working width; enclosed operator's cab with fresh air intake filter. Dedicated to K061 treatment.	120,000
- 1-6CY dump truck.	45,000
- 1-Bob-Cat front-end loader for landfill operation.	40,000
- 1 compactor, sheep-foot or equal	35,000
- 1-Troxler Nuclear moisture gage, model 3411	3,000
- 2 Soil Test Penetrometers, Model CL-700 for compaction	100
Sub-Total	367,600
20 Percent Contingency	73,500
Total Capital	$441,100
Rounded	$442,000
Above estimates based on 1983-1984 data; updated for 6 percent per annum increase for labor, materials, and overhead.	$526,000

Capital Costs (onsite stabilized waste disposal)

Landfill design based on EPA minimum technology guidance for single liner secure landfill (EPA/530-SW-85-013, May 24, 1985).

Item	Cost,$
Landfill Installation Cost (10-year landfill life): 11.25 acres x 100,000/acre*	1,125,000
Total capital costs (for stabilization facility and onsite secure landfill)	1,651,000
Cost of acquiring a RCRA Part B permit for an onsite TSDF**	100,000
Total Capital Cost	$1,751,000

Operating Costs	Cost,$/Yr
Lime Kiln Dust:** 11,000 TPY @ $100/ton delivered	$110,000
Labor: $7.50/ton EAF waste (Center for Metals Production 1985)	83,000
Proprietary Stabilizing Materials **	10,000
Onsite Disposal Cost: 22,000 TPY @$10/ton (Center for Metals Production 1985)	220,000
Total Operating Cost	$423,000

* Based on actual costs obtained for new synthetic single liner-equipped, leachate collection landfills. Costs include excavation, site preparation, membrane liner installation, and leachate collection and storage system.

** Audit team estimate.

Annual pre-tax operating savings of this option over present annual K061 disposal costs: $1,000,000 - $423,000 = $577,000.
Capital payback period (pre-tax):

1,751,000/577,000 = 3.0 years.

Assuming an economic life of 5 years (20 percent amortization per year), the internal rate of return is 20 percent (Riggs 1982).

The annual cost of stabilized waste preparation and disposal under this option is ($423,000 + 350,000)/22,000 or $35/ton, as compared to the current disposal cost of $100/ton.

Proposed Resource Recovery Option for K061 Waste

As discussed previously, the St. Joe Flame Reactor process may be a viable commercial option for Plant No. 3, permitting recovery of zinc and lead values, with the balance of the material disposed of as nonhazardous waste. The process would be operated on site and the plant owned by the EAF steel manufacturer. Projected capital and operating cost data (provided by St. Joe Mineral, Monaca, Pa.) are presented for this process:

Plant Capital Cost	$1,500,000
(Plant to process 10,000 TPY of K061 waste filter cake (prior to drying this material) and 1,000 TPY of K061 dust)	
Operating Cost	$/Year
(Based on 8,000 TPY dry K061 waste and 300 days per year operation)	
Coke/coal fines	88,000
Oxygen	294,000
Electricity	23,000
Natural gas	14,000
Labor	84,000
Other direct overhead	80,000
Total Direct Operating Cost	$583,000
Amortized Capital Cost and Profit	$400,000

Crude recovered zinc oxide value (assumed directly proratable based on the St. Joe assumed zinc level of 20 percent in the raw K061 waste, as compared to the actual level of 8 to 10 percent in Plant No. 3 K061 waste). Value of recovered oxide shown includes costs for control of other volatile pollutants generated in the process. Recovered zinc oxide sold as secondary smelter feed.	$188,000
Cost for nonhazardous slag disposal (assume 7,200 TPY @ $10/ton)	72,000
Net annual cost to Plant No. 3 (Direct Operating Cost + Amortized Capital Cost + Profit + Slag Disposal Cost - Recovered Oxide Value)	$ 867,000/yr
Net Cost/Ton K061 waste	$ 108/ton

This cost exceeds the present cost to Plant No. 3 for disposal of K061 waste ($100/ton) in offsite hazardous waste landfills. This option cannot be totally eliminated from consideration, however, despite the present uncertainties as to its availability and the applicability to K061 waste with low zinc levels. It is important to note that not only will the plant's present waste disposal cost increase over the next few years, but the planned hazardous waste landfill ban may eliminate all available sites for disposal of this waste.

SUMMARY AND DISCUSSION

With waste minimization options (source reduction and recycle) not available at Plant No. 3, an alternative treatment option to the present method of handling and disposing of EAF steelmaking heavy metals waste (K061) has been studied by the audit team. The treatment option is as follows: the chemical stabilization/solidification of EAF dust and sludge, with the subsequent delisting of the treated waste and disposal in a dedicated onsite nonhazardous waste landfill, has been subjected to a preliminary engineering feasibility study. Based on this study, the proposed treatment option appears technically and economically feasible. A summary of the preliminary economics of this option (for 10-year onsite disposal) indicates the following:

• Total capital cost	$1.75 million
• Annual operating cost	$0.42 million/yr
• Estimated payback period	3 years
• Estimated internal rate of return (based on an economic life of 5 years)	20 percent

• Present annual K061 waste generation rate	11,000 TPY
• Proposed annual treated K061 waste generation rate	22,000 TPY
• Cost of treatment and disposal of waste	$35/ton
• Annual savings (over amortized life of treatment plant and onsite landfill) if this option were implemented	$227,000/year

The audit team findings on the proposed treatment option were discussed with Plant No. 3 personnel. The latter agreed that this is the only feasible option available to them at this time. However, the steel company's laboratory studies on K061 waste stabilization to date have indicated that there is a problem preventing leaching of chromium from the stabilized waste, and thus a likelihood of failing the EPA TCLP leaching test. The audit team believes that the use of additives such as soluble silicates in the stabilization mixing process could cause the formation of stable, insoluble chromium silicates, which could render the stabilized material non-leachable. A continued laboratory effort in this direction appears warranted.

SECTION 6

EVALUATION OF THE USE OF THE WMA PROCEDURE

ACCOMPLISHMENTS OF PLANT VISIT

The pre-audit visit was an invaluable aid in establishing the waste streams that could be amenable to the benefits of a WMA. During this visit, a tour of the plant operations generating the various hazardous wastes established that a hazardous waste stream at each plant studied at the EAF steelmaking complex had the potential for waste minimization. Following the identification of these three waste streams, the audit team requested and received appropriate flow sheets, permit data, material balance information, plant layout data, and equipment specifications relating to these streams. In this regard, the willingness of the plant management to provide all needed data was invaluable in understanding the operations that generate the wastes under consideration.

The formal audit visit demonstrated that one-to-one contacts between the members of the audit team and plant personnel are necessary to obtain all of the facts pertinent to the wastes being studied. Otherwise, the audit team could draw incomplete and erroneous inferences on how processes could be altered or materials recycled, to minimize generation of the hazardous waste involved. In this regard, Plant No. 1 personnel deemed worthwhile the audit team's proposal to recover calcium fluoride (fluorspar) as a 30 percent moisture filter cake off the existing vacuum belt filter for recycle to the Plant No. 3 EAF steelmaking operation as metallurgical flux. However, they advised the audit team of an important consideration in the use of additives in the EAF steelmaking process - the requirement that these materials be dry and in briquetted or pelletized form in order to be successfully used in the process. These two considerations were subsequently factored into the proposed fluorspar recovery process and its related costs.

The effectiveness of the interactive process was further enhanced by the willingness of Plant No. 1 personnel (at the suggestion of the audit team) to get outside technical advice and information from engineers in the company's central engineering group on proposed options about which the local personnel were not sufficiently informed. In particular, a proposed option to eliminate the need to treat Kolene waste (at Plant No. 1) for chromium reduction by the addition of sodium hydride to the molten Kolene descaling bath (in-situ hexavalent chromium reduction) was discussed with technical personnel in the company home office. The option had to be discarded because of the occurrence of a side reaction forming cyanide, which ultimately would have to be destroyed before the treated Kolene waste could be disposed of.

BENEFITS OF OPTIONS DEVELOPED DURING WMA EFFORT

Plant No. 1

The K062 waste currently generated at Plant No. 1 is neutralized with the precipitated solids ultimately trucked to an offsite nonhazardous waste landfill and the treated wastewater discharged under an NPDES permit. Two problems are encountered, however: (1) the plant is having difficulty achieving a 7 ppm fluoride permit limit, which is mandated to become effective in 1988 (it is presently treating to about 15-20 ppm fluoride in the discharged wastewater), and (2) the wastewater treatment sludge (although nonhazardous) must be hauled off site for disposal at considerable expense. The proposed option, if implemented, would appreciably mitigate these two problems, as well as enable a valuable byproduct to be recovered for in-house use (fluorspar). With regard to the two problems cited above, the audit team sees the following benefits of implementing of the proposed option:

- The 1988 NPDES fluoride limit of 7 ppm should be achievable, since the bulk of the fluoride is recovered in the initial selective precipitation step as recovered calcium fluoride, reducing the solubility of the residual fluoride during the final neutralization step.

- It is possible to achieve a 30 percent reduction in the tonnage of solids needed to be disposed of off site.

Plant No. 2

The combined K062 waste currently generated at Plant No. 2 is neutralized with the precipitated solids held in onsite lagoons and the treated wastewater discharged under an NPDES permit. Segregation of waste ferrous sulfate/sulfuric acid pickle liquor (one of the components

of the K062 waste), as well as use of this material in Plants No. 1 and 3 for hexavalent chromium reduction, not only eliminates present purchases of ferrous sulfate heptahydrate for this purpose, but extends the life of the waste lagoons by reducing the amount of sludge deposited there after waste neutralization.

Plant No. 3

Disposal of K061 waste in offsite hazardous waste landfills by Plant No. 3 may become not only prohibitively expensive as available landfill space diminishes, but could face elimination as a waste disposal practice when the mandated landfill bans take effect. By using the proposed detoxification technique on the waste, i.e., stabilization/solidification followed by delisting and onsite disposal (dedicated acreage would be available for this purpose), Plant No. 3 is offered a potential alternative to the present disposal method. This alternative, however, does not succeed in minimizing K061 waste generation or permit recycle and/or recovery of any of the components of this waste.

SECTION 7

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